Nuclear Power

THE JOURNAL OF BRITISH NUCLEAR ENGINEERING

We work for the New Age

THE AGREEMENT between Mitchell Engineering Ltd of London and AMF Atomics Inc of New York, will undoubtedly have far-reaching effect in applying atomic power for the benefit of mankind.

Created for the joint design and construction of nuclear power plant in the Commonwealth and other countries, it is private industry's first international agreement in this field — and the logical outcome of Mitchell's exceptionally wide experience over the past 35 years in all branches of engineering and electrical supply.

MITCHELL COMPANIES—active in the atomic sphere since 1950—are at present engaged on three important contracts for the United Kingdom Atomic Energy Authority.

MITCHELL

MITCHELL ENGINEERING LIMITED ONE BEDFORD SQUARE LONDON WCI
MITCHELL CONSTRUCTION COMPANY WHARF WORKS PETERBOROUGH

February 1957 Volume 2 Number 10 3s 6d

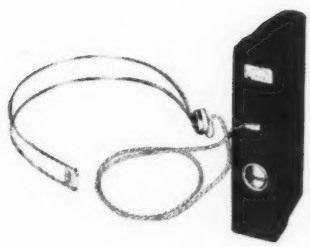
Remote Handling Equipment
for radioactive and toxic materials
SAVAGE AND PARSONS LIMITED
WATFORD · HERTFORDSHIRE · ENGLAND
TELEPHONE: WATFORD 4711

HEALTH INSTRUMENTATION

BY **PHILIPS**

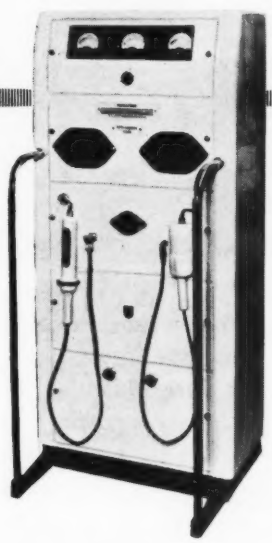
The units illustrated here are selected from Philips range of monitoring equipment designed to safeguard the health of workers in atomic factories and research establishments. Full details will gladly be sent on request.

Philips, with their many years' experience in the field of radiation measurement, are best qualified to advise on all health instrumentation problems.



Pocket Battery Monitor type PW 4010. Sensitive to gamma rays, high energy beta radiation and X-rays, with ranges for high and low sensitivity. Low intensities also audibly detectable by earphones. Ideal for intensity measurements in laboratories, checking radio-active sources or tracers, etc. *A product of N.V. Philips, Eindhoven, Holland.*

Contamination Meter type 1092D. Accurately measures gamma activity on clothing, benches, etc. Interchangeable power supply units : high tension battery, mains unit, or vibrator. Cold cathode valves throughout obviate need for filament heating and help to reduce size, weight and maintenance. *Developed in conjunction with U.K.A.E.A., Harwell.*



A number of these monitors have been supplied to Calder Hall

Hand and Clothing Monitor type 1404A. Enables workers to rapidly check their hands and clothing for harmful contamination. The instrument incorporates hand units for detecting beta-gamma radiation and, below these, two frisking probes for checking the clothing for beta-gamma and alpha radiation. Special care has been taken in design to ensure ease of cleaning and quick replacement of contaminated parts. *Developed in conjunction with U.K.A.E.A., Harwell.*

Write or telephone for full details of the complete Philips range of health monitoring equipment.

PHILIPS

PHILIPS ELECTRICAL LTD

RESEARCH AND CONTROL INSTRUMENTS DIVISION

CENTURY HOUSE • SHAFTESBURY AVENUE • LONDON • W.C.2

TELEPHONE : GERrard 7777 (PSE0203)

A Complete Equipment:—

The above illustration shows a complete equipment for liquid G.M. counting techniques. The apparatus comprises Scaler, Power Unit, Pre-Amplifier, Lead Castle & 10 ml. Counter Tube together with Rack Mounting Cabinet and Interconnecting Leads. A Ratemeter is also shown being used for pre-sampling by utilising the standard beta/gamma tube as a dipping counter, after removing the probe cover.

The entire equipment can be supplied ready for immediate operation within a few days of receipt of order for £284 net, delivered in the United Kingdom. The Laboratory Ratemeter is similarly available for £78.

Further details will gladly be sent on request to:—

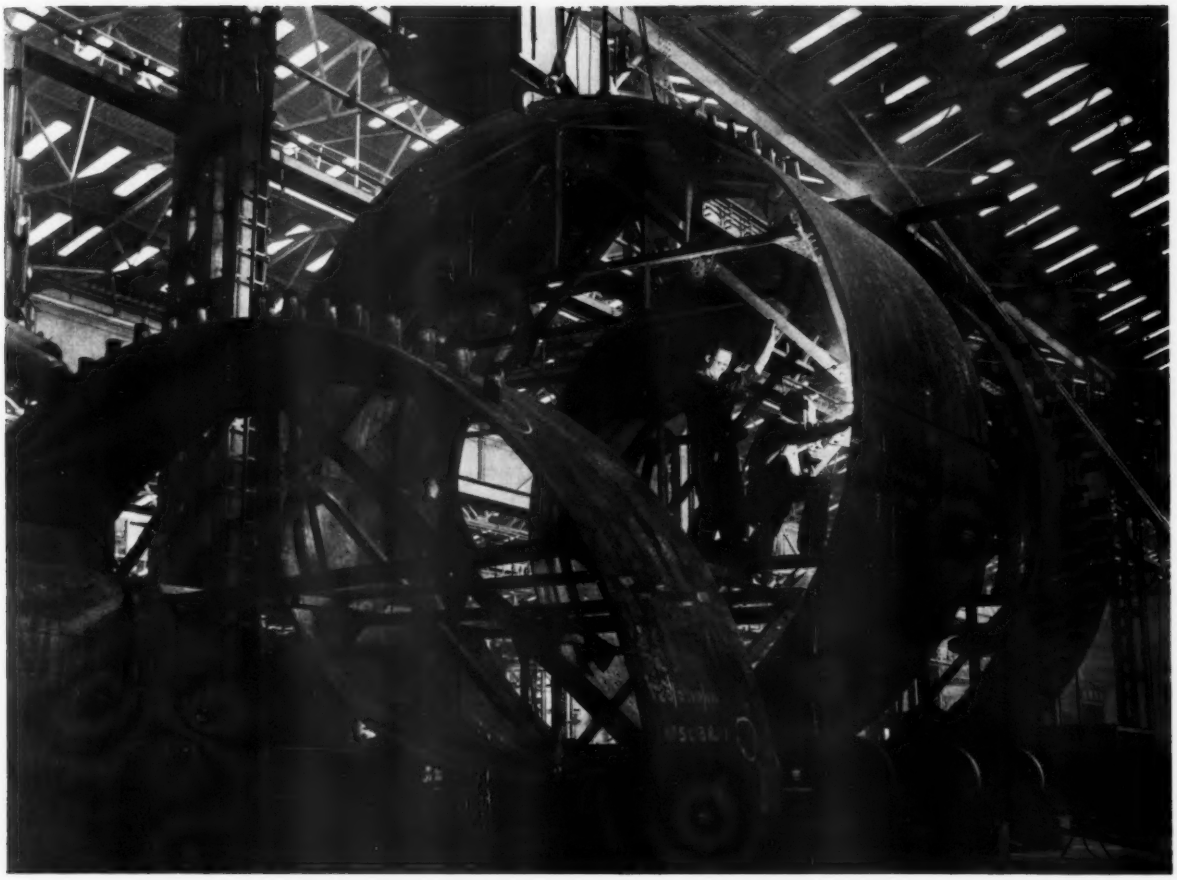
Labgear (Cambridge) Ltd.

NUCLEONICS DIVISION

WILLOW PLACE, CAMBRIDGE, ENGLAND

Telephone:
Cambridge 2494 (2 *lines*)

Telegrams:
"Labgear Cambridge"



Manufacture of shell sections for the steam-raising towers of Calder Hall Atomic Power Station. [*Courtesy of Babcock & Wilcox Ltd.*]

Steam-raising at Calder Hall

The steam-raising plant at Calder Hall, designed and built by Babcock & Wilcox Ltd., consists of 16 welded steel towers, each 80 feet high, 17 feet in diameter and containing over ten miles of complex steel tubing. On the tubes of each tower are welded 11,000,000 fins of aerofoil section to provide the maximum surface for heat exchange with minimum resistance to the flow of gas.

In this plant carbon dioxide gas, raised to a high temperature in the nuclear reactor, is circulated under pressure over the finned steel tubes, transforming the water in the tubes into superheated steam.

Every joint in the steam-raising plant has to be perfect. All important welds, therefore, were subjected to critical radiographic inspection. Kodak 'Industrex' X-ray Film played an important part in this vital inspection job.

Kodak INDUSTRIAL X-RAY FILMS

—first choice of inspection engineers

A catalogue is available giving full details of the latest materials and equipment for industrial radiography. Send for your free copy.

Kodak Limited, Industrial Sales Division, Kodak House, Kingsway, London, W.C.2

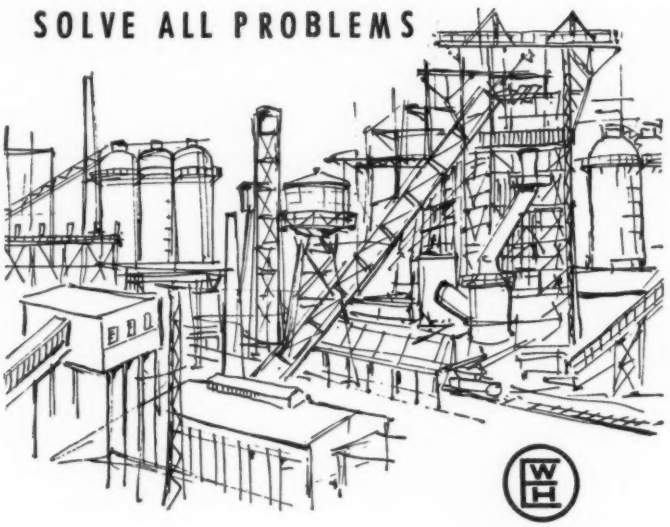
'Kodak' and 'Industrex are trade-marks

THE WORLD-WIDE-FAMOUS

ERHARD
VALVES

known for their Design, Precision and Quality for more than 80 years.

SOLVE ALL PROBLEMS



JOHANNES ERHARD H. WALDENMAIER ERBEN
Süddeutsche Armaturenfabrik, Heidenheim / Brenz - Germany
Telephone 3881 Cable: Erhardarmaturen

For all information write to:

The Sole Agents for the United Kingdom

A.K. STARCK'S CO. LTD. 22, Chancery Lane London W.C. 2
Telephone Holborn 2966 Cable: Akstar London

Shaping the Future

Skill doesn't come easily. It has taken more than 12 years of close association with the development of Atomic Energy for Marstons to build up the specialized technical knowledge they possess in this field. Marston Excelsior, from the start, have been among the foremost suppliers of specialized equipment to the U.K.A.E.A.— equipment for the first large-scale diffusion plant in this country; plate type fuel elements for the research reactors Dido, Lido and Dimple; stainless steel gas coolers for Calder Hall. It is this past experience that is helping Marstons to shape the future with such precision.

MARSTON EXCELSIOR LIMITED

ICI **Fordhouses, Wolverhampton**

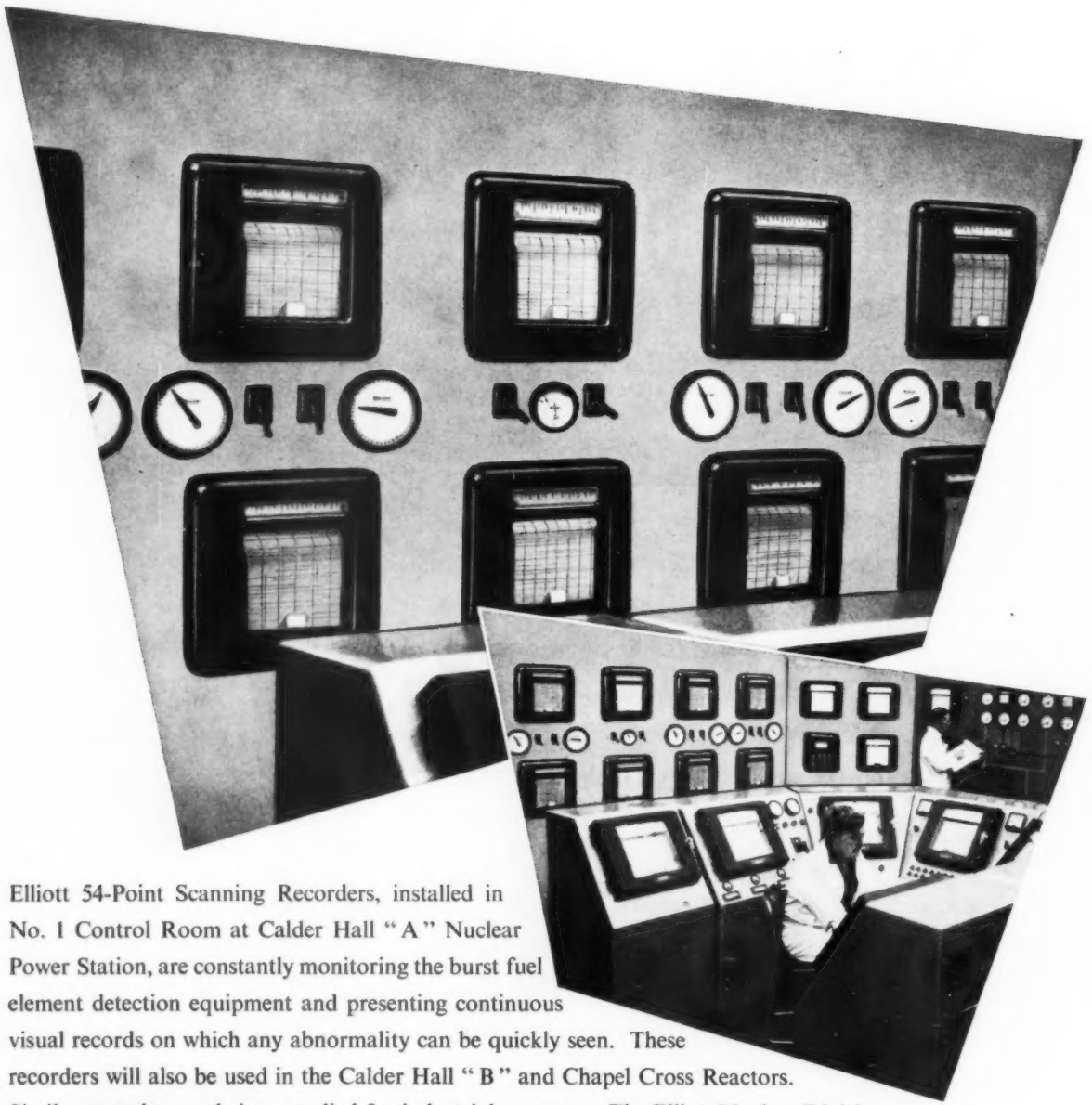
(A subsidiary of Imperial Chemical Industries Limited)

AT CALDER HALL

this complex bundle of precision made tubes is part of the monitoring system. In any problem of specialized fabrication, Marstons will most likely have the answer.

MAR.193

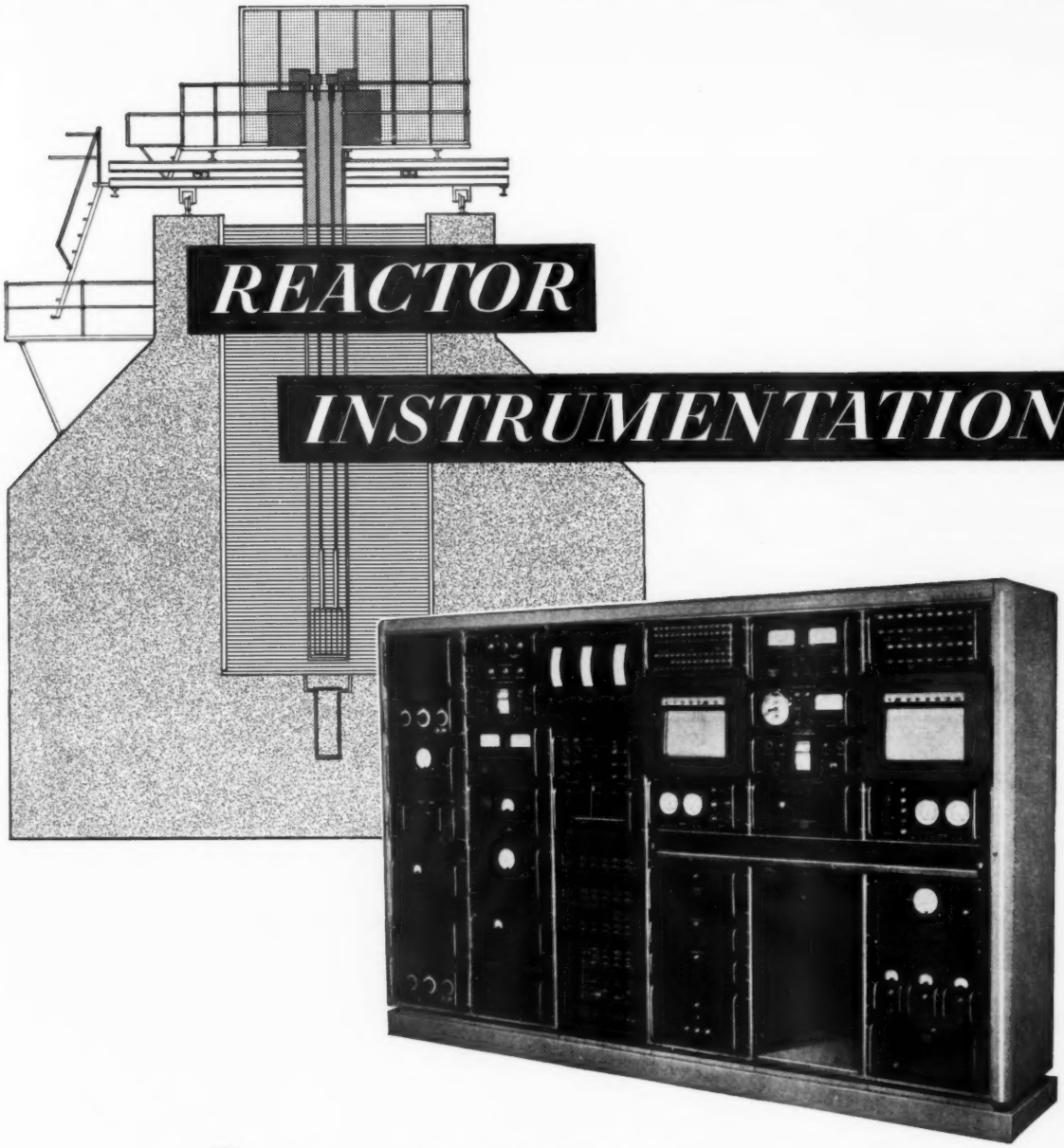
ELLIOTT at Calder Hall



Elliott 54-Point Scanning Recorders, installed in No. 1 Control Room at Calder Hall "A" Nuclear Power Station, are constantly monitoring the burst fuel element detection equipment and presenting continuous visual records on which any abnormality can be quickly seen. These recorders will also be used in the Calder Hall "B" and Chapel Cross Reactors. Similar recorders are being supplied for industrial processes. The Elliott Nuclear Division is specialising in the design and manufacture of reactor instruments and controls, thus supplementing the wide range of industrial control equipment available from the Company. The services of the Elliott organisation are offered to the Atomic Energy Industry for the complete instrumentation of reactor power stations.

CONSULT ELLIOTT FOR INSTRUMENTATION AND CONTROL OF NUCLEAR ENERGY

ELLIOTT BROTHERS (LONDON) LTD., CENTURY WORKS, LONDON, S.E.13 (TIDEWAY 1271 and 3232)



REACTOR INSTRUMENTATION

THE MEASUREMENT, CONTROL AND HEALTH INSTRUMENTATION

FOR

'LIDO'

SWIMMING POOL REACTOR

WAS DESIGNED AND INSTALLED TO A.E.R.E. SPECIFICATION

BY

T E L INSTRUMENTS

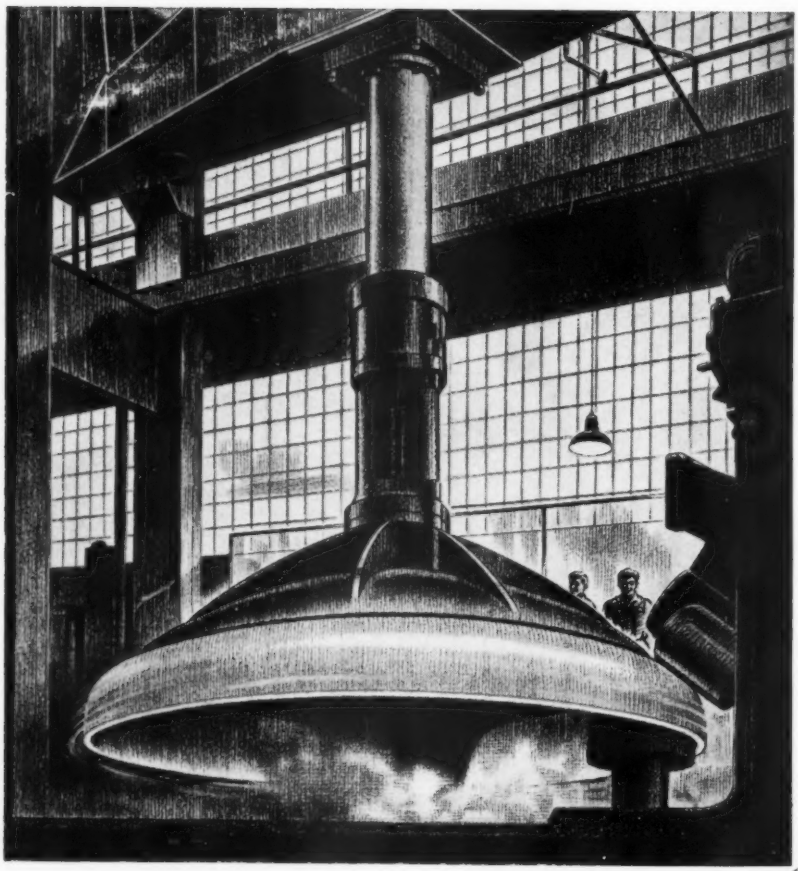
A DIVISION OF ERICSSON TELEPHONES LIMITED

Enquiries to: THE INSTRUMENT DIVISION, HIGH CHURCH STREET, NEW BASFORD, NOTTINGHAM. *Telephone:* NOTTINGHAM 75115

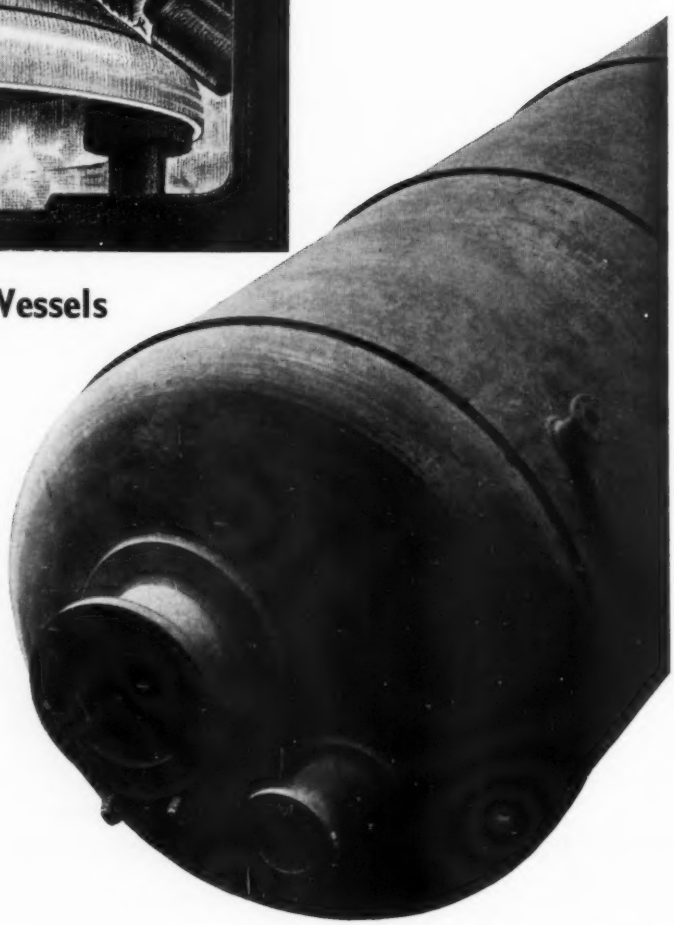
Spinning

SAVES METAL

—CUTS TOOL COSTS



The design and production of Pressure Vessels may be greatly facilitated by using dished and flanged ends spun by Harveys on the Rotarpress. They combine semi-ellipsoidal form with large knuckle radius. A substantial reduction in plate thickness can be effected, and in most cases tool costs are eliminated.



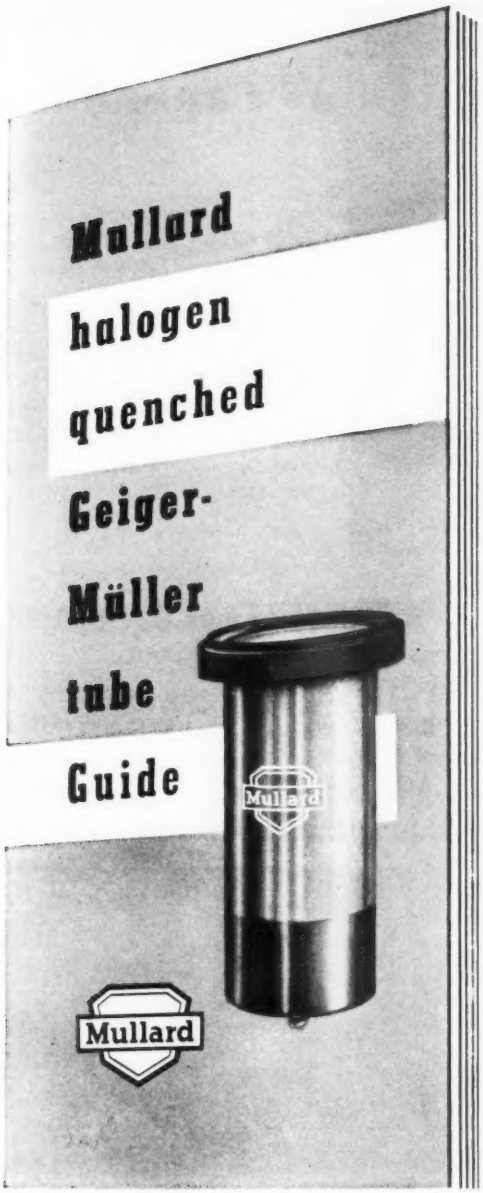
'Rotarprest' Ends for Pressure Vessels

can be supplied in Mild, Alloy and Clad Steels and Non-ferrous Metals. The capacity of the Rotarpress ranges from 5 to 15 feet diameter, and $\frac{3}{8}$" to 4" thickness. Knuckle radii and depth may be varied to meet individual requirements.

Please ask for List No. NP 965 giving full range of sizes.

Harvey

G. A. HARVEY & CO. (LONDON) LTD.
WOOLWICH ROAD - LONDON, S.E.7
Telephone: GREenwich 3232 (22 *lines*)



Do you use Geiger Müller Tubes?

To meet an ever growing demand in the fields of medicine research and industry, Mullard have developed a comprehensive range of Geiger Müller Tubes that includes types for almost every application.

Then get your copy of this valuable tube guide

This guide has been prepared to assist users of Geiger Müller Tubes in selecting the right tube from the Mullard range for optimum performance in any given application. It is a valuable source of reference. Make sure of your copy by writing to the address below now.

It will help you choose the best tube for the job

To Mullard Limited, X-ray Division, New Road, Mitcham Junction, Surrey.
Please supply us with..... copies of your Geiger Müller Tube Guide.

NAME .....

ADDRESS .....

.....

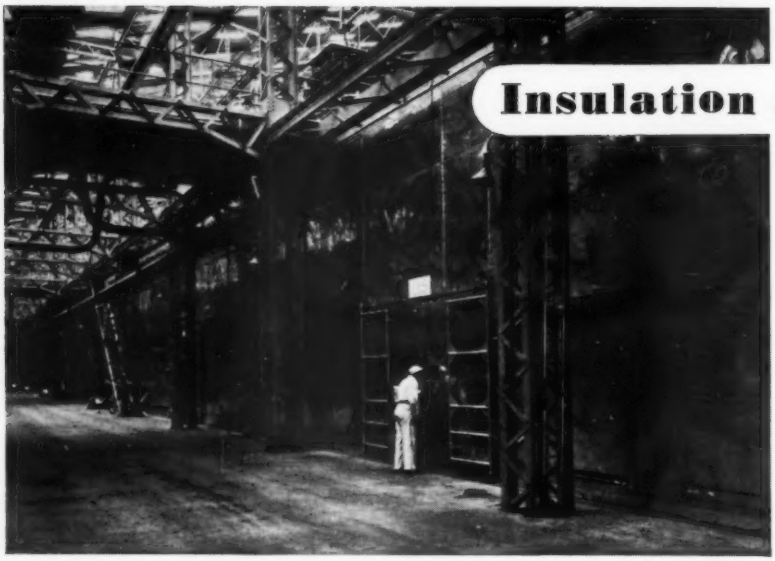
.....

Mullard

X-RAY DIVISION

MULLARD LTD., X-RAY DIVISION,
NEW ROAD, MITCHAM JUNCTION, SURREY
Telephone: Mitcham 3471

MXR 530



Insulation at Capenhurst

For Cell Cladding many thousands of panels were used. These comprised heavy density cork faced with Sheet Aluminium to a modular size 8′ x 4′ in 1″ and 1½″ thicknesses, the joints being covered with solid Burma Teak strips.

We manufacture a variety of composite materials in this field for cladding, insulation and shielding purposes.

Architects: T. L. Viney, A.R.I.B.A., R. S. Brocklesby, A.R.I.B.A. Chief Architects to the Industrial Group of the Atomic Energy Authority

Contractors: Trollope & Colls Ltd

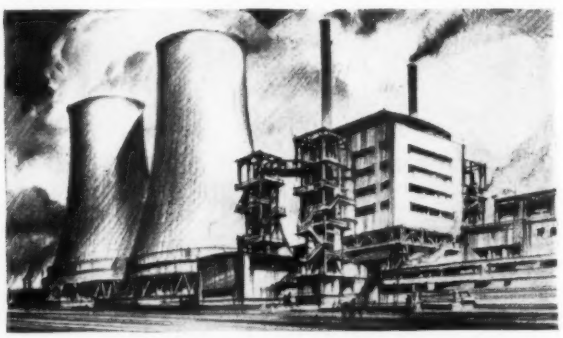
William Mallinson and Sons Ltd.

TIMBER and VENEER MERCHANTS

130-150 HACKNEY ROAD · LONDON · E.2

Telephone: Shoreditch 7654 (15 lines) *Telegrams:* "Almoner," London

MANUFACTURERS OF PLYWOOD, ARMOURPLY, PANELS, COMPOSITE PARTITIONING AND INSULATING BOARDS



VOKES GENSPRING

specified for Calder Hall

Vokes Genspring pipe support systems are acknowledged to be the finest and most accurate available. As the first unit in a revolutionary departure from normal power generation, Calder Hall must have only the best in equipment—and for this important pioneer in nuclear power generation, we supplied C. A. Parsons & Co. Ltd., one of the main contractors for this station, with the latest in the range of Vokes Genspring Constant Support Hangers to support the mass of complex piping.

Vokes W.3 and W.4 hangers and their associated fittings are used extensively in both the 'A' and 'B' stations. The hangers shown can withstand a load of 30,000 lb. over a travel of 3¾ ins. or 8,400 lb. over 12 ins.

SUSPENSION SYSTEMS BY

VOKES GENSPRING

VOKES GENSPRING LIMITED · GUILDFORD · SURREY

VG/11

GORDON

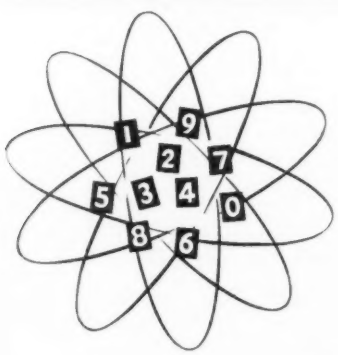
first FOR

CONTROL VALVES OF ALL SIZES FOR CO_2, FLUE GAS, STEAM, WATER, ETC.

AND

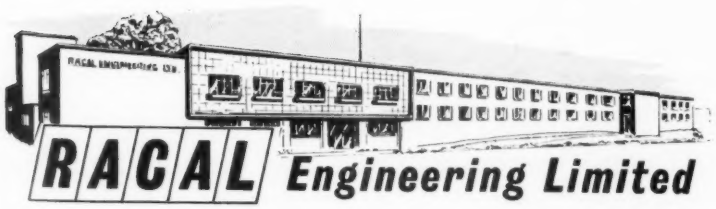
VALVE OPERATORS WITH REMOTE OR AUTOMATIC CONTROL

JAMES GORDON & CO. LTD., DALSTON GARDENS, STANMORE, MIDDLESEX.(WORDSWORTH 3631)



Digits in the nuclear pie

Digital counting techniques, developed in Britain by Racal, can answer many measurement and control problems in nucleonics, from high-speed precision timing and tachometry to pulse counting and delay generation. Alongside complete equipments for standard application ranges, Racal offer fourteen individual types of plug-in units (decade dividers, scalers, totalisers, triggers, gate control units, pulse invertors and cathode followers) which by their easy " permutation " enable special-purpose equipment to be built-up quickly, easily adapted and serviced. The economics are impressive, too.



RACAL *Engineering Limited*

BRACKNELL · BERKSHIRE
Telephone: BRACKNELL 941
Cables/Grams: RACAL BRACKNELL BERKS

North England Agent:
Farnell Instruments Ltd., Hereford House, North Court, Vicar Lane, Leeds, 2. Tel: Leeds 32958.

Fleming
RADIO (DEVELOPMENTS) LTD.

CRYSTAL - CONTROLLED PULSE GENERATOR

TYPE 1478A

. . . provides accurate pulses for calibrating ratemeters and scalers; the constant output pulse, with an attenuator, enables checking of amplifier gains, and/or discriminator triggering sensitivity levels. Scaling-tubes on the divider-panels give visual indication of the decade dividing circuits.

Developed in collaboration with the U.K. Atomic Energy Authority, Harwell.

FREQUENCY: 100 kc/s down to 1 c/s in decades: a ÷ 2, ÷ 4 switch permits selection of intermediate frequencies.

PULSE OUTPUT (VARIABLE): 5 volts to 20 volts (into 1000pf). Polarity: positive or negative. Width: 2 μ secs. Rise-time: ·1 μ sec.

PULSE OUTPUT (CONSTANT): Approximately 1 volt into attenuator. Polarity: negative Width: 2 μ secs. Rise-time: ·1 μ sec. Attenuator: 83db in 1db ± 1 % steps (image impedance 100 ohms).

GATING CIRCUIT: This enables 1-sec. " bursts " of pulses to be available at any given frequency for the calibration of scalers.

STAB'LITY: The decade frequencies remain constant with an H.T. variation of ± 5%, or a mains input variation of ± 15%.

MAINS VOLTAGE: 200-250 volts, 50 cycles.

All enquiries to: **Fleming** RADIO (DEVELOPMENTS) LTD.

Designers and Manufacturers of :— Logarithmic Ratemeters, Radio-Active Dust Sampling Equipment, Time Base Equipment, X-Ray Dose Meters, Linear Amplifiers, Quench Amplifiers, Gamma-Radiation Monitors, Scintillation Counters.

CAXTON WAY, STEVENAGE, HERTS. (Stevenage 804)

THE MORGAN *Megistor*

MARK I

A HIGH VALUE, GLASS ENCLOSED RESISTOR,

OF HIGH STABILITY COVERING THE RANGE 10^7 to 10^{14} OHMS.

APPROVED BY THE M.O.S. TO A.E.R.E. SPECIFICATION 390.

Further information may be obtained from :

THE MORGAN CRUCIBLE COMPANY LIMITED

'Y' DEPARTMENT, NORTON WORKS, WOODBURY LANE, NORTON, WORCESTER

Telephone : WORCESTER 66912 *Telegrams :* CRUCIBLE, WORCESTER

Y.50

NON FERROUS METALS

ESTABLISHED 1780

THE HOUSE OF

SMITHS

OF

CLERKENWELL

Offer the most comprehensive stock available

FOR THE NUCLEAR ENGINEER

BRASS · DURALUMIN	RIVETS
COPPER · ALUMINIUM	NUTS
PHOSPHOR BRONZE, ETC.	SCREWS, ETC.

J. SMITH & SONS (CLERKENWELL) LTD.

42-54 ST. JOHN'S SQUARE, CLERKENWELL, LONDON, E.C.1

Phone : CLErkenwell 1277 (14 *lines*)

It can't be done without CONTROL

Did you ever let off a Fifth of November rocket that finished up by going through someone's bedroom window? If you have, you can appreciate the kind of confidence these boffins have in their control over the rockets they design to investigate the stratosphere, ionosphere and the rest of that great nothingness out there.

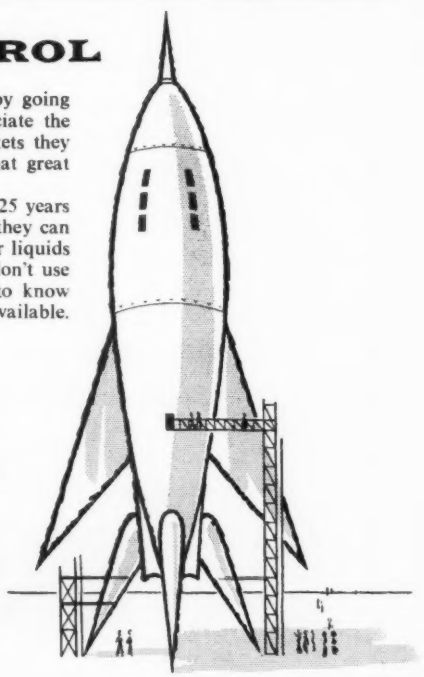
We at Magnetic Valve admire this attitude, for we too have spent 25 years building reliable and efficient control into our products until today they can control, automatically or remotely, a whole host of industrial gases or liquids (such as air, steam, oil or coal gas) with absolute efficiency. They don't use stuffing-boxes, glands or driving shafts either. If you would like to know more about our standard range, we have some illustrated literature available. Special valves up to 12 in. orifice can be supplied.

Many valves avai'able ex-stock. Valves designed for special conditions.

MAGNETIC BALANCED 3-WAY VALVE

This valve can be used to control air, water, oil and other liquids, normally passed through a pipe where it is required to operate Diaphragm Valves, Single Acting and Double Acting Cylinder mechanisms, etc. Standard valves are suitable for controlling pressures up to 70 lbs. per sq. in. or 100 lbs. per sq. in. as required. This type of valve is capable of operating at high speeds over long periods.

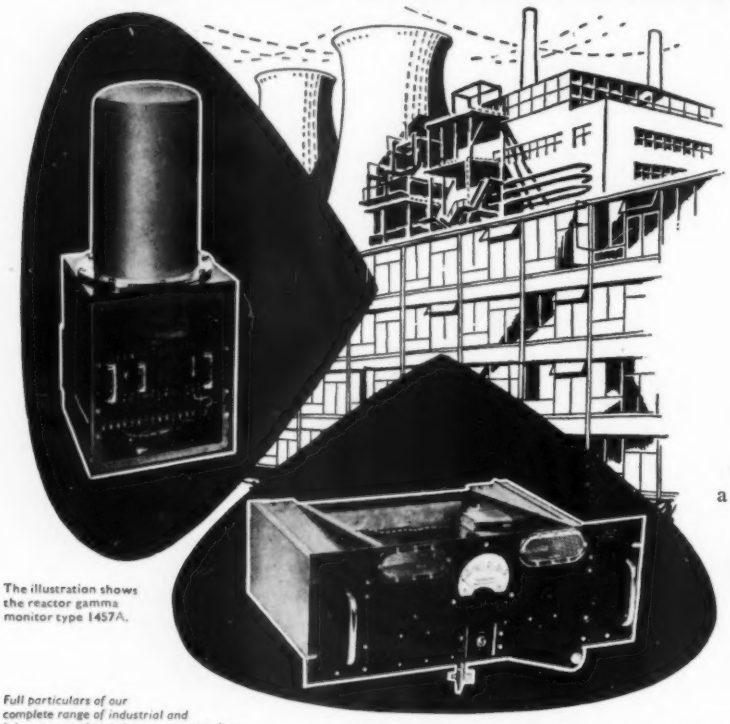
A Flameproof solenoid housing, Buxton Certified, can be fitted where required.



the Magnetic Valve Company LIMITED

28 ST. JAMES'S PLACE · LONDON · S.W.1 · Tel.: HYDe Park 7588

Calder Hall uses I.D.L. Nucleonic Instrumentation



The illustration shows the reactor gamma monitor type 1457A.

Isotope Developments Limited, as specialists in the industrial and research application of atomic energy, are playing a part in the instrumentation of the Calder Hall Power Reactor.

Besides specific instruments for Calder Hall, Isotope Developments are engaged upon an extensive programme of commercial reactor instrumentation. Amongst their present projects are the Nucleonic instrumentation of the "Merlin" (Medium Energy Research Light Water Moderated Industrial Nuclear Reactor) experimental reactor produced by the A.E.I. John Thompson Nuclear Energy Co. Ltd., and acting as consultants and suppliers of instruments for a number of European and overseas reactors.

We are exhibiting at the Physical Society Exhibition Stand No. 6A, New Horticultural Hall Westminster, S.W.1 March 25—28, 1957

ISOTOPE DEVELOPMENTS LTD.

Full particulars of our complete range of industrial and laboratory nucleonic instrumentation from;

ISOTOPE DEVELOPMENTS LTD.

Laboratories & Works: Beenham Grange, Aldermaston Wharf, Nr. Reading, Berks. *Tel: Woolhampton 451/3*
London Office: 120 Moorgate, London, E.C.2. *Tel: METropolitan 9641*

COCKBURNS LTD · FULLSAFE · WORLD SAFETY

Almost a century of Valve Manufacture has contributed to the design of Safety Valves specially developed for the Main Cooling Circuit of the Reactor System.

COCKBURNS
OF CARDONALD

COCKBURNS LTD. CARDONALD · GLASGOW · S.W.1.

Service and Maintenance Depot at

45 BACK UNION ROAD · FISH QUAY · NORTH SHIELDS

COLLOIDAL GRAPHITE ...in electronic and allied fields

Coatings or films formed with this versatile product are, for practical purposes, chemically and physically inert; they can be used in close proximity to radio-active material and are transparent to radio-active emanations. The many applications for 'dag' colloidal graphite include the lubrication of reactor control mechanisms, louvres and sliding surfaces; the treatment of screw threads to prevent seizure, dry film and high temperature lubrication for I/c engines, air compressors, pumps, reduction gears, and for ball, roller or plain bearings under conditions of high load, stress or speed.

An Acheson service engineer will be pleased to call on you, or technical leaflets will be sent on request.

dag
REGD TRADE MARK
DISPERSIONS

ACHESON COLLOIDS LTD., *18, PALL MALL, LONDON, S.W.1*
Telephone: Whi 2034-9 *Telegrams: Oildag-Piccy-London*

SINGLE PHASE AND POLYPHASE WATTHOUR METERS
SYNCHRONOUS TIME SWITCHES
SYNCHRONOUS MOTORS AND MOTOR UNITS

SANGAMO WESTON

PANEL & SWITCHBOARD INSTRUMENTS
D.C. Moving Coil, A.C. Rectifier, H.F. Thermocouple A.C./D.C. Moving Iron

PORTABLE INSTRUMENTS
D.C. Moving Coil, A.C. Rectifier, H.F. Thermocoupie A.C./D.C. Moving Iron, A.C./D.C. Dynamometer

LABORATORY STANDARD INSTRUMENTS
D.C. Moving Coil, A.C./D.C. Dynamometer

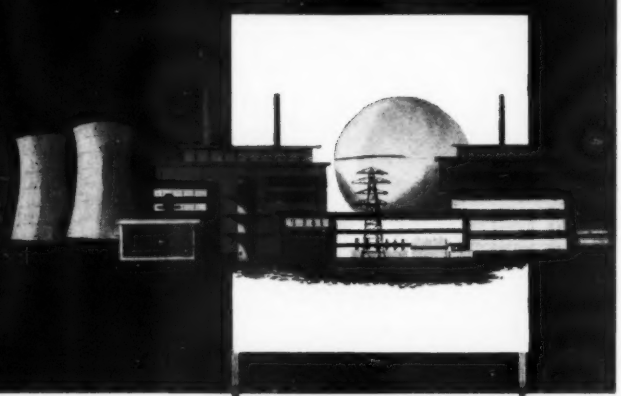
CURRENT TRANSFORMERS
FREQUENCY METERS
ALL-PURPOSE TEST SETS
AIRCRAFT INSTRUMENTS
RATIOMETERS . TACHOMETERS
ELECTRICAL THERMOMETERS
WESTON STANDARD CELLS
"PHOTRONIC" PHOTO ELECTRIC PHOTOMETERS

SANGAMO WESTON LTD.
ENFIELD, MIDDLESEX
Telephone: ENField 3434 (6 lines) and 1242(6 lines)
Grams: Sanwest, Enfield
Scottish Factory: Port Glasgow, Renfrewshire Port Glasgow 41151

Branches: London, CHAncery 4971 . Glasgow, Central 6208 Manchester, Central 7904 . Newcastle-on-Tyne, Newcastle 26867 Leeds, Leeds 30867 . Liverpool, Central 0230 . Wolverhampton, Wolverhampton 21912 . Nottingham, Nottingham 42403 Bristol 21781 . Southampton, Soton 23328 . Brighton, Brighton 28497

SW/15

Power and Performance in AUTOMATIC SETS



Constantly leading in the realm of diesel development, Crossley Brothers manufacture a wide range of automatic sets, which incorporate the soundest constructional designs in diesel manufacture.

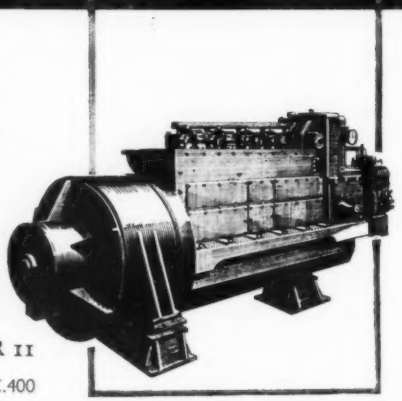
These sets are eminently suitable for "standby" duties, and are proving themselves to be capable of producing the same consistant high standard of performance that makes Crossley synonymous with efficiency.

Typical sets are those to operate automatically on:

★ *Failure of the main electricity supply*

★ *Increases in power requirement*

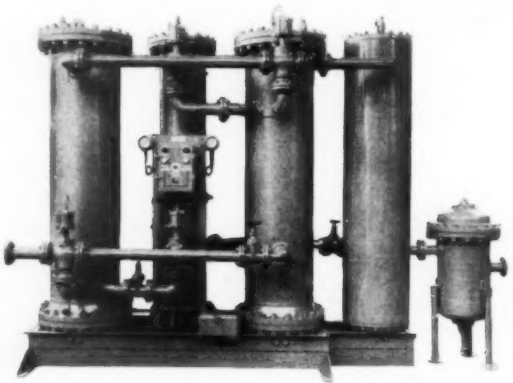
★ *Pressure drops in booster or fire/sprinkler systems, etc., etc.*



CROSSLEY DIESEL ENGINES

CROSSLEY BROTHERS LIMITED, OPENSHAW, MANCHESTER 11

London Office: Langham House, 308 Regent Street, W.1 ℗ C.400



SILICA GEL LIMITED

SPECIALISTS IN

COMPRESSED AIR DRYING FOR INSTRUMENTATION

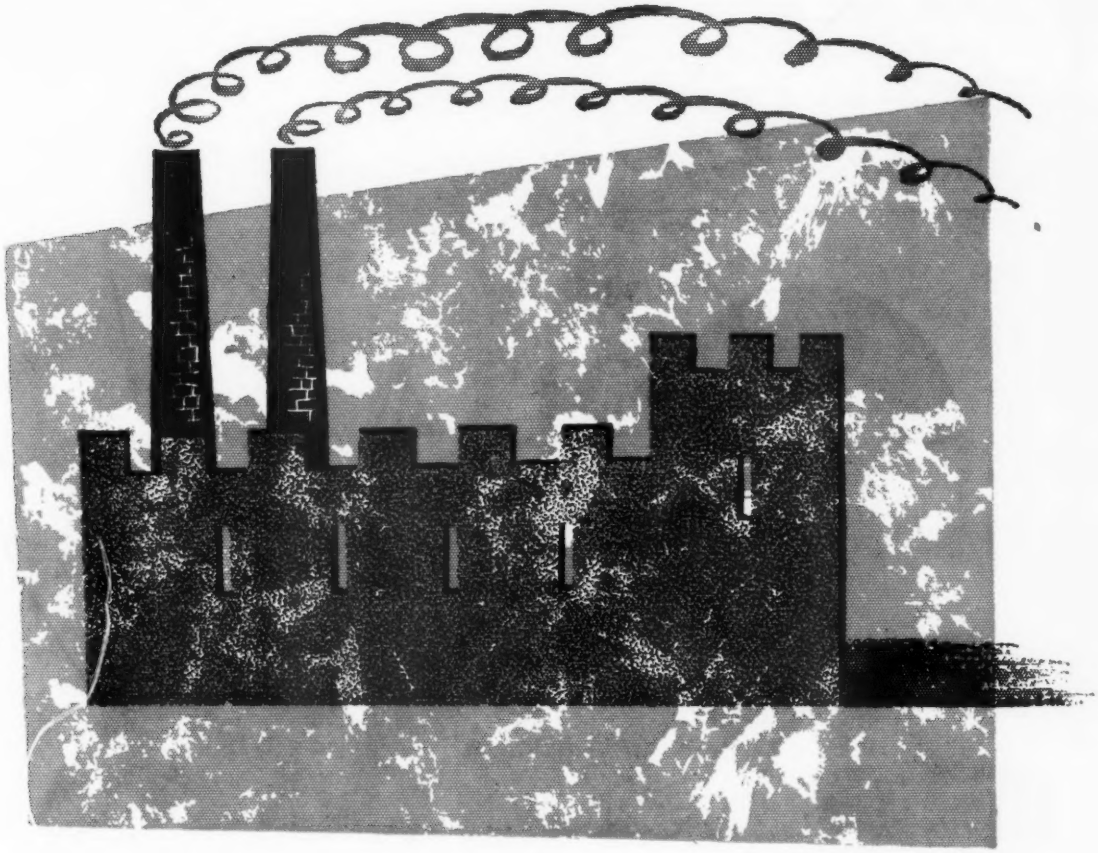
LOW PRESSURE DRYING FOR THE MANUFACTURE OF RADIOACTIVE ISOTOPES

BREATHERS FOR TRANSFORMERS

ENQUIRIES TO:
HEAD OFFICE
ASTORIA HOUSE
62, SHAFTESBURY AVENUE
LONDON, W1

WORKS AT:
HOUNSLOW
MIDDLESEX

Still in the Middle Ages?



Or using ***Epikote Resins***
for structural protection?

Epikote Resins, made by Shell, are now being used in surface coatings designed to combat corrosion of steel structures under the most arduous conditions. Epikote Resin based coatings are exceptionally resistant to chemical reagents including solvents. They have proved themselves effective against liquid and atmospheric contamination, even under conditions of high humidity. Wherever Epikote Resins are on guard maintenance costs are cut to a new low level. Your paint supplier will give you further details.

SHELL

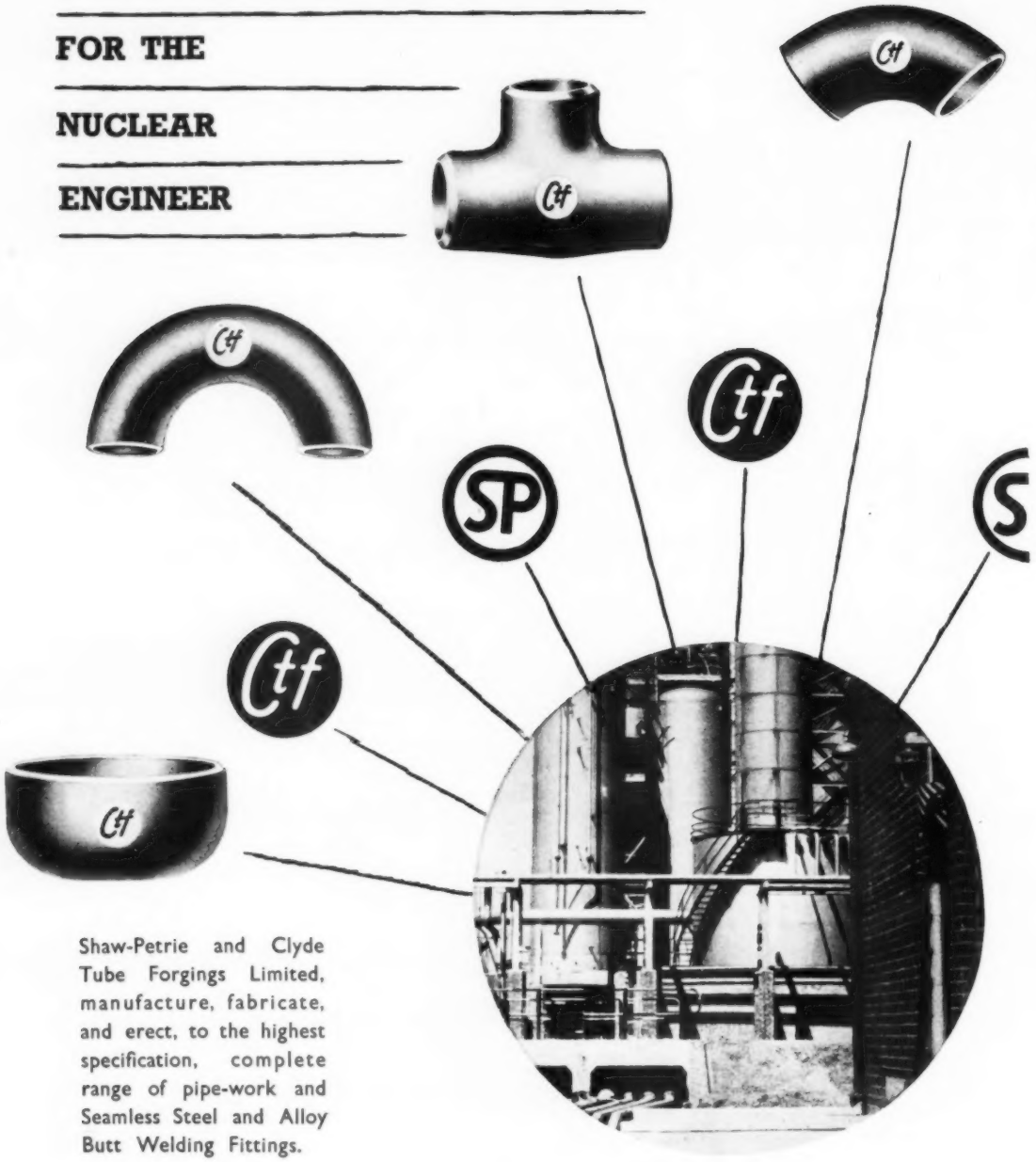
***Epikote Resins** defy corrosion as never before!*

SHELL CHEMICAL COMPANY LIMITED, 105/109 Strand, London, W.C.2. *Tel: TEMple Bar 4455*

EPIKOTE is a Registered Trade Mark.

E.S.P.3.

PIPE INSTALLATIONS FOR THE NUCLEAR ENGINEER



Shaw-Petrie and Clyde Tube Forgings Limited, manufacture, fabricate, and erect, to the highest specification, complete range of pipe-work and Seamless Steel and Alloy Butt Welding Fittings.

SHAW-PETRIE LIMITED | **CLYDE TUBE FORGINGS LTD**

NORTH HILLINGTON · GLASGOW SW2 · TELEPHONE HALFWAY 5551-6

LONDON OFFICE 157 VICTORIA ST. SW1
TELEPHONE TATE GALLERY 9325-6
AND AT SOUTH SHIELDS, LIVERPOOL AND BELFAST

OVERSEAS
CANADIAN CLYDE TUBE FORGINGS
P.O. BOX 278 WESTON ONTARIO

New Zealand · *Barbados* · *Mexico and*
East West · *British Guiana* · *Venezuela*
Central and · *Jamaica* · *Belgium Holland*
South Africa · *Trinidad* · *Norway Sweden*
Australia · *Italy Spain* · *and Finland*

CLYDE TUBE FORGINGS OF AMERICA
PORTLAND OREGON U.S.A.

NUCLEAR POWER STATIONS

HUMPHREYS & GLASGOW LTD. invites enquiries for the design and installation of Nuclear Power Plants with outputs ranging up to 20 MW in any part of the world outside the North American Continent. Power costs are competitive with conventional stations of equivalent sizes.

HUMPHREYS & GLASGOW LTD.

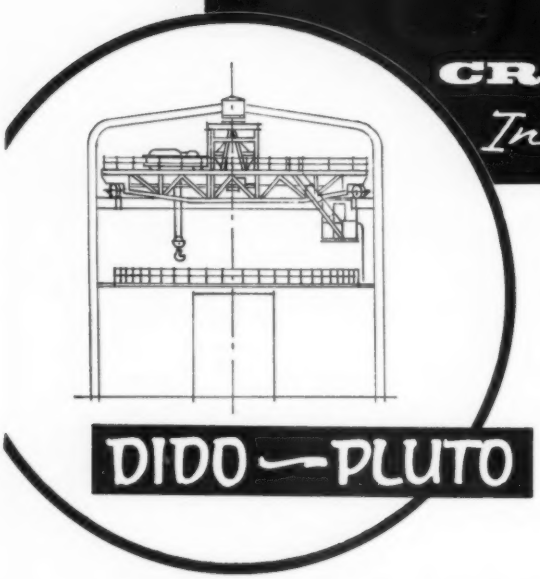
HUMGLAS HOUSE · CARLISLE PLACE · LONDON · S.W.1

Telephone: VICtoria 8454

ALSO IN CANADA · AUSTRALIA · FRANCE · GERMANY · INDIA · SOUTH AFRICA · JAPAN

CRANE MAKING

In the Atomic field



DIDO — PLUTO

In collaboration with the Ministry of Works Engineering Staff we designed and installed a special form of circular motion Overhead Electric Travelling Crane, for operation in Britain's first experimental Reactor at Harwell.

We will shortly complete the installation of further circular motion units at both Harwell and Dounreay, the latter on instructions from the United Kingdom Atomic Energy Authority.

During the early part of 1957 we will commission a similar crane for the Australian Atomic Energy Commission.

The cranes are designed for a lift of 25 tons on a span of approximately 67 ft.

We are currently engaged in the installation of Main Turbine House and Blower House Cranes for Calder "B" and Chapel Cross Atomic Power Stations.

THE WHARTON CRANE & HOIST CO. LTD.

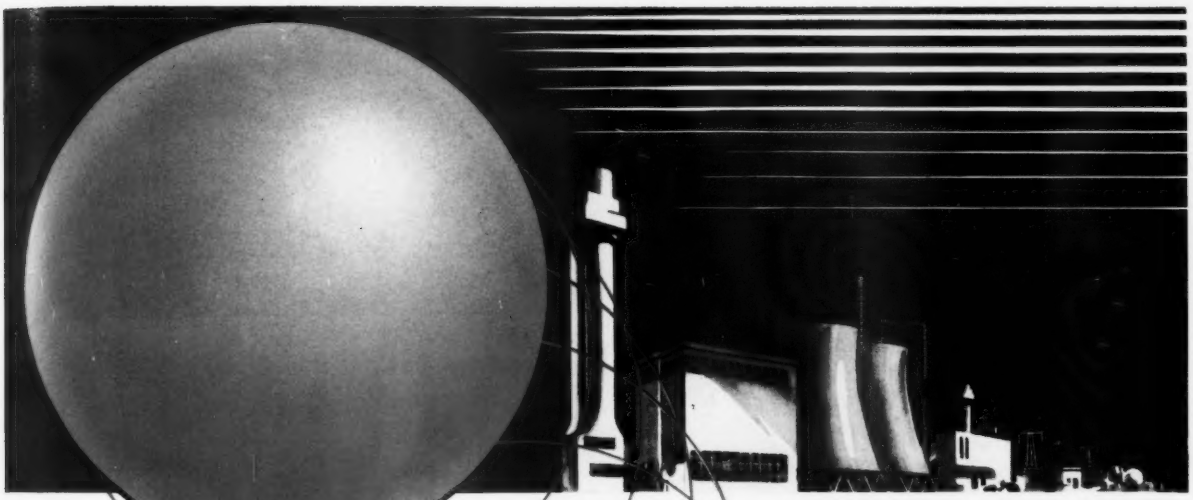
REDDISH STOCKPORT ENGLAND

Phone : Heaton Moor 2227. Grams : "Gallant, Manchester." Code: Western-Union

London : Lincoln Chambers, Portsmouth Street, London W.C.2. Tel Chancery 7911

Scotland : Fisher, Baxter & Co., 140 West George Street, Glasgow. C.2.	Phone : Douglas 1061-2-3	Grams : 'Fluorspar' Glasgow
Midlands : A. R. Holland & Son, 89 Cornwall Street, Birmingham, 3.	Phone : Central 1457.	Grams : Central 1457, Birmingham
South West : R. C. Collins, 48 Westbourne Road, Penarth, Glamorgan.	Phone : Penarth 1527.	Grams : Penarth 1527
Northern Counties : Fisher, Baxter & Co., 140 West George St., Glasgow, C.2.	Phone : Douglas 1061-2-3.	Grams : Fluorspar, Glasgow.
Northern Ireland : General Engineering Products Ltd., 44-46 Waring Street, Belfast.	Belfast Tel : 23743	
Eire or Southern Ireland : Charles Nolan & Co., 2 Parker Hill, L. Rathmines Road.	Phone : Dublin 93510	Grams : Dublin 93510

REPRESENTED IN PRINCIPAL COUNTRIES THROUGHOUT THE WORLD.



WHATEVER THE SOURCE...

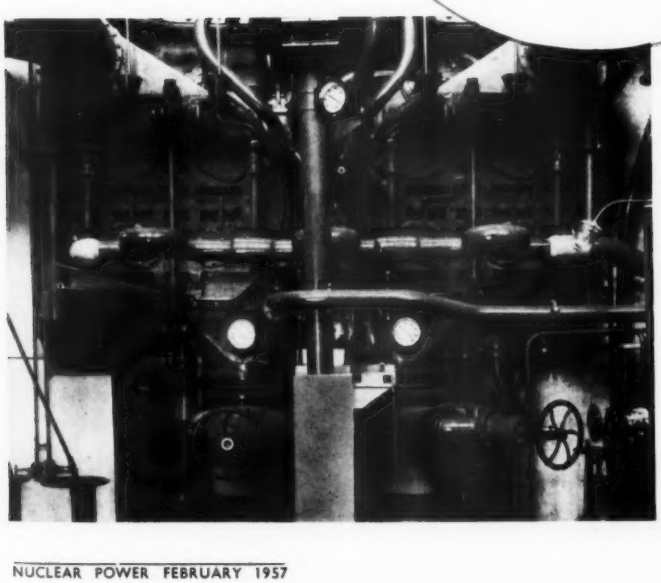
Weirs meet the Changing Conditions with Unchanging Skill

The reliability and high efficiency in design, materials and performance associated with Weir Auxiliaries for steam installations are now being applied to Weir equipment for Nuclear Power plant.

Research, development, design and maintenance of the highest standard, maintain Weir leadership in the auxiliary field, whatever the source of energy.

We invite consultation on all questions relating to design and manufacture of Pumps, Valves, Heat Exchangers and other Auxiliaries for Nuclear Power circuits.

In the rapidly changing field of power reactor technology, the expert assistance which we can give on such equipment is essential.



G. & J. WEIR LTD.
CATHCART · GLASGOW

Welding a "Sirocco" Backward Aerofoil Bladed Fan runner

behind the "SIROCCO" trade-mark...

there are 75 years of specialised experience in fan engineering, that extends from original design right through every stage of manufacture to the final testing. "Sirocco" men mostly grow up in the job, and to a tradition of craftsmanship that means there is more to every "Sirocco" product than meets the eye. It is this essential "know how" that costs you nothing and can save you much.

The expert advice of a "Sirocco" trained engineer from our nearest Branch is at your service, without any obligation on your part.

It will pay you to investigate "Sirocco" service if you are interested in

FANS FOR HANDLING AIR AND OTHER GASES • HEATING AND VENTILATING OR COMPLETE AIR CONDITIONING • FUME AND VAPOUR REMOVAL • DUST COLLECTION PNEUMATIC CONVEYANCE

DAVIDSON & CO. LTD.

SIROCCO ENGINEERING WORKS
BELFAST, NORTHERN IRELAND

London · Manchester · Glasgow · Birmingham · Newcastle-on-Tyne · Leeds · Cardiff

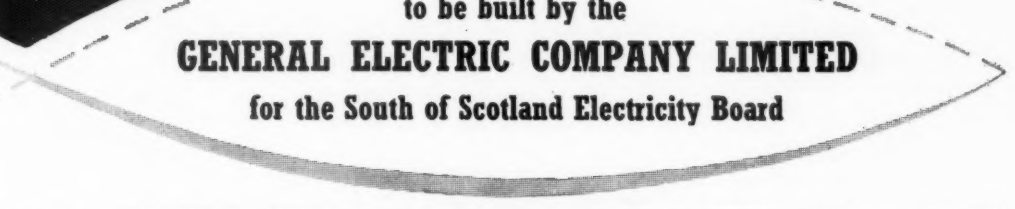
POWELL DUFFRYN
CARBON PRODUCTS LIMITED

are proud to announce that they have been appointed the sole machinists of

NUCLEAR GRAPHITE

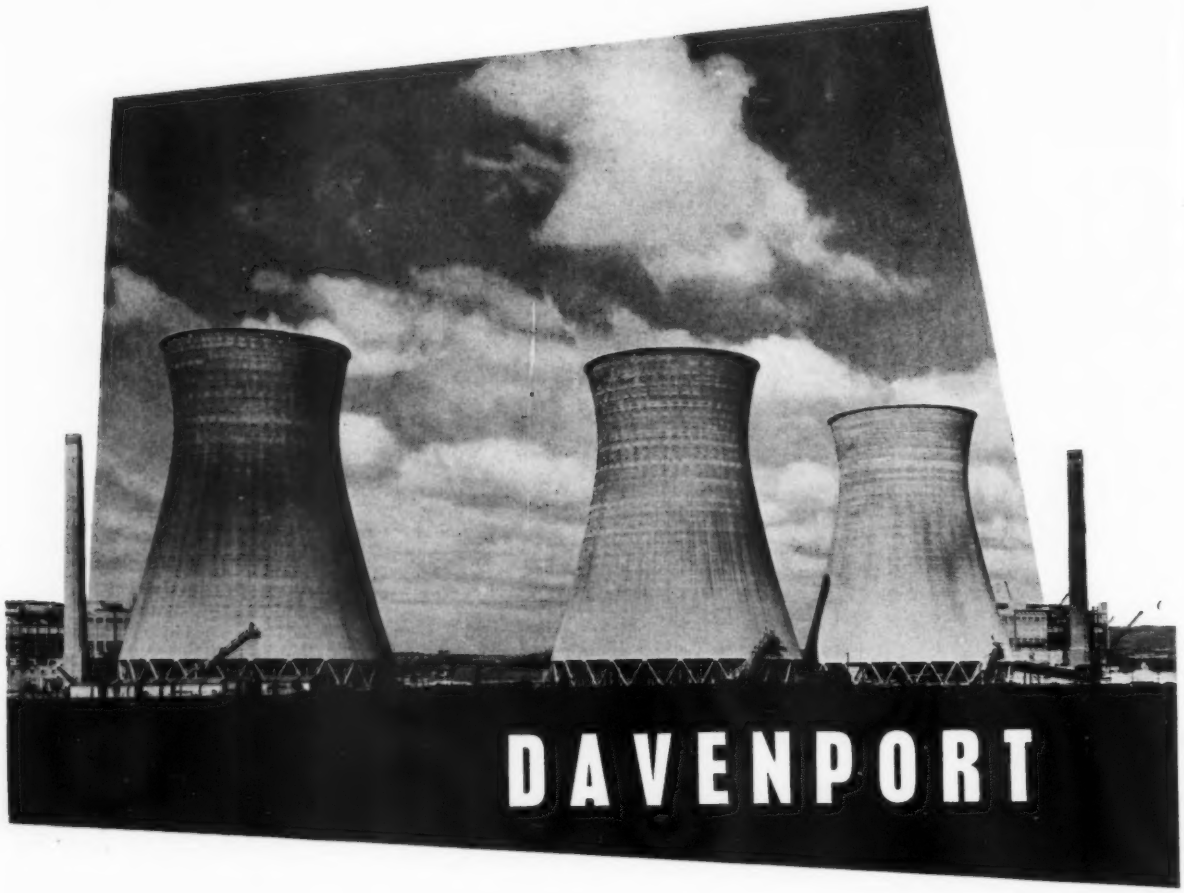
FOR THE WORLD'S LARGEST ATOMIC POWER STATION

to be built by the
GENERAL ELECTRIC COMPANY LIMITED
for the South of Scotland Electricity Board



POWELL DUFFRYN CARBON PRODUCTS LIMITED

SPRINGFIELD ROAD, HAYES, MIDDLESEX. TELEPHONE: HAYES 3994



SPECIALISTS IN THE
DESIGN AND
CONSTRUCTION OF
COOLING TOWERS
SINCE 1910

THE DAVENPORT ENGINEERING CO., LTD., HARRIS STREET, BRADFORD, 1
Telephone: Bradford 29361

It all started from there

Atomic power is a force that is now under control. Power stations are being built to use it both here and overseas, and these are only the forerunners of those to be built during the next few years. Talbot Stead are manipulating tubes for incorporation in the stations now being erected, and even more tubes will be required for the stations of tomorrow. Their manipulative skills will be taxed more and more as new alloys are called into use, and as the complexity of the assemblies increases. But Talbot Stead can be depended on to keep up with the needs of this specialised section of industry. If you are concerned with any form of tube manipulation Talbot Stead will welcome the opportunity to discuss the specification with you. They may be able to take on a job that is too complex for your own staff; they may be able to do work now in progress on a more economical basis.

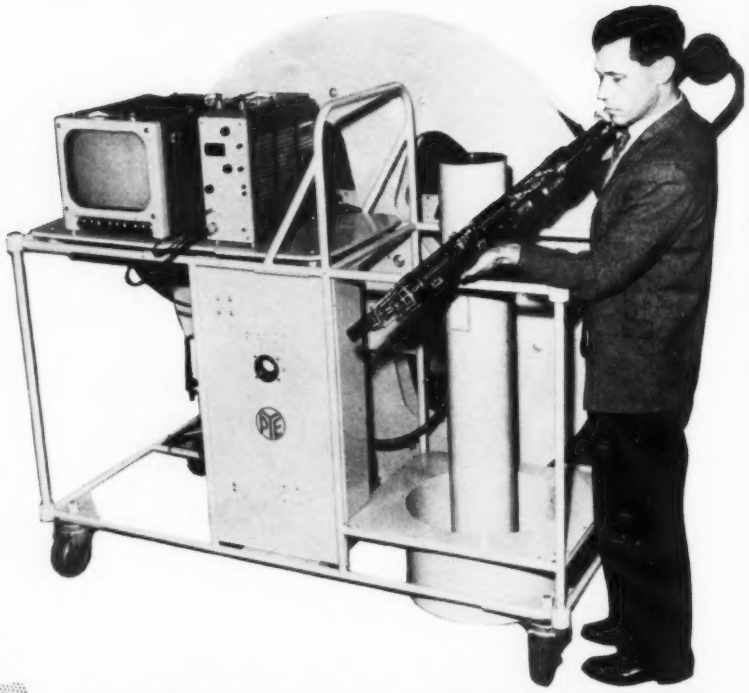
Talbot Stead

manipulated tubes for atomic energy

MANUFACTURERS OF: CARBON, ALLOY AND STAINLESS STEEL TUBES · 'METICA' METAL CLAD CARBON AND GRAPHITE TUBES · BI-METAL TUBES · 'METIOR' SANITARY PIPE FITTINGS · MACHINED FLANGES AND COMPONENT PARTS · 'FORJEND' STAINLESS WELDING FITTINGS · CARBON, ALLOY AND STAINLESS DRAWN AND GROUND BARS AND WIRE · 'CUFFORD' DIAPHRAGM VALVES

TALBOT STEAD TUBE COMPANY LIMITED · GREEN LANE · WALSALL · A TI COMPANY

TSW 9



The special camera is shown here without its stainless steel casing. Beside it is the trolley with control unit, monitor and cable.

INDUSTRIAL TELEVISION at CALDER HALL

This illustration shows the camera in its stainless steel casing.

After demonstrating industrial television to the Atomic Energy Authority last year, Pye Limited were given a contract to design a special camera capable of being used inside an atomic reactor at the Authority's Cumberland factory. This has now been completed and has been delivered to Harwell for tests prior to its use at Calder Hall. For ease of manipulation, the camera carries its own source of illumination consisting of a series of four small but powerful bulbs grouped around the camera's lens. In addition, a remotely controlled rotatable mirror enables all-round viewing to be obtained.

As the equipment is to be used while the atomic pile is dangerous, the camera can be remotely controlled and is housed in a thin stainless steel casing 3½ inches in diameter and 30 inches long. The whole apparatus, involving the camera and its 75 feet of cable, the control unit and the monitor, is mounted on a trolley so that it is ready for instant use. As the camera is liable to be exposed to temperatures of up to 200°C, the control cables leading to the camera head are enclosed in a flexible hose through which carbon dioxide is pumped to cool the cables and camera. Radio-active dust can be removed from the camera, after its withdrawal from the reactor, by washing down.

A second camera, which is now being made, is to be supplied to the Authority within the next few months and will be used as a standby.

Wherever it is too difficult or too dangerous to use a human observer, Pye Industrial Television comes into its own. In diverse uses as far apart as whaling ships and opera houses, Pye Industrial Television is increasing efficiency and cutting costs. Your firm may have a use for it. Write to Pye for further details or a demonstration.

PYE LTD., INDUSTRIAL TELEVISION DIVISION

98, Highbury New Park, London, N.5 CANonbury 3215, 5271

REACTOR CHARGE TUBES FOR ATOMIC POWER STATIONS

The Unit Superheater and Pipe Company Limited, as sub-contractors to Whessoe Ltd., supplied the reactor charge tubes for station 'A' at Calder Hall. Further sets of charge tubes are also being made for Calder Hall 'B' station and Chapelcross.

In accordance with Lloyds' requirements, each weld is subjected to a radiographic test. The total number of films required to cover the welding on the eight sets of tubes for both these projects will be 14,000.

'Unit' have been further entrusted with the supply of reactor tubes for the new station at Bradwell.

The Unit Superheater and Pipe Company Limited, fabricators of pipework for modern high pressure and temperature steam conditions, are also able to offer a complete radiographic service, using either radioactive isotopes or X-rays.

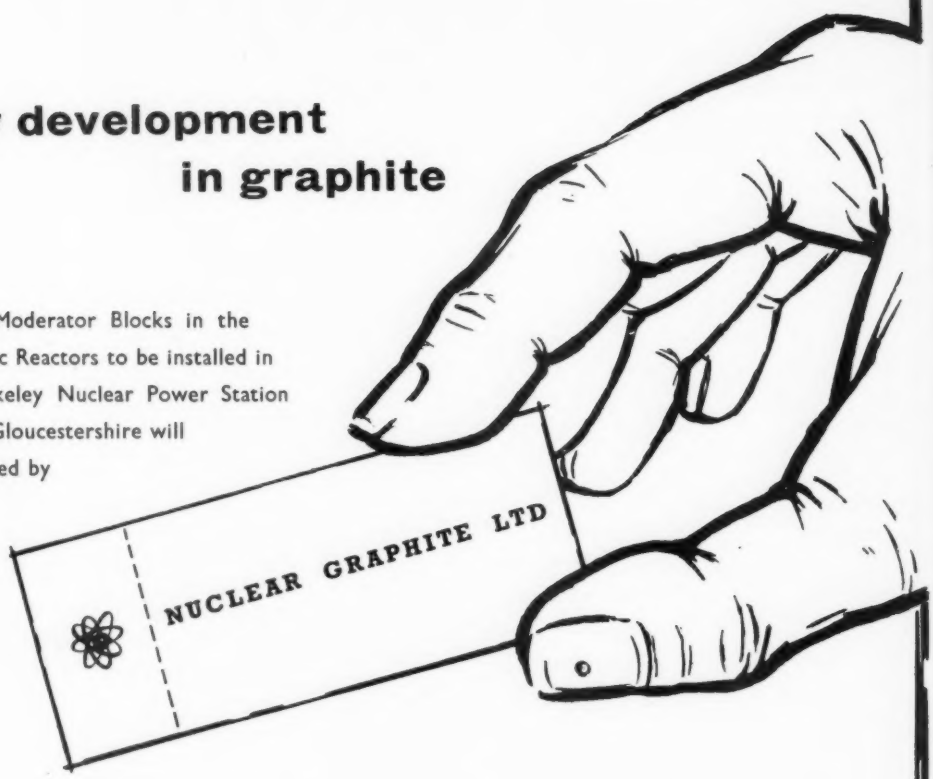
THE UNIT SUPERHEATER AND PIPE CO., LTD.

Unit Works, Swansea. Telephone: Swansea 54091 (6 lines). Telegrams: 'Superunits', Swansea. Telex: 48-208

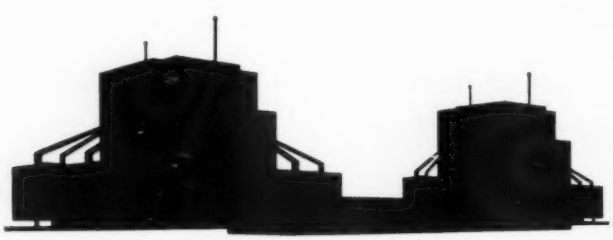
UNIT

A new development in graphite

Graphite Moderator Blocks in the Atomic Reactors to be installed in the Berkeley Nuclear Power Station in Gloucestershire will be machined by



This is a new company which has been formed in association with A.E.I.—John Thompson Nuclear Energy Company Ltd. To the strength and knowledge of this Company, The Morgan Crucible Company Limited will add the specialised technical knowledge and skills gained from 100 years of practical experience in the handling of graphite and carbon. The resources of NUCLEAR GRAPHITE LTD. will be available for machining graphite blocks for nuclear reactors—so helping to control the atom for peaceful power.



MORGANS

CARBON AND GRAPHITE—ELECTRICAL, CHEMICAL AND MECHANICAL; ELECTRONIC & RADIO PARTS; REFRACTORIES; SINTERED METAL PRODUCTS; ELECTRIC FURNACE ELEMENTS, CRUCIBLES AND FURNACES.

THE MORGAN CRUCIBLE COMPANY LTD., BATTERSEA CHURCH ROAD, LONDON S.W.11
BATtersea: 8822

NGIA

XUNG

HOWDEN

In nuclear engineering, blowers are required for moving large volumes of gas against a substantial resistance.

At Windscale Atomic Energy Station, for example, there are sixteen Howden single-stage blowers, each delivering 240,000 cubic feet per minute at 59-inch water gauge and driven by a 3,000 b.h.p. motor.

These blowers are the most powerful of their kind in this country, with an exceptionally high efficiency, and have been giving continuous trouble-free service since their installation in 1950.

JAMES HOWDEN & COMPANY LIMITED

195 SCOTLAND STREET, GLASGOW, C.5 and 15 GROSVENOR PLACE, LONDON, S.W.1

Specialists in the design
and manufacture of equipment for

MOVING OR COMPRESSING AIR AND GASES

TRANSFERRING HEAT
FROM ONE FLUID TO ANOTHER

CLEANING AIR AND GASES

THE

G.E.C.

SIMON-CARVES

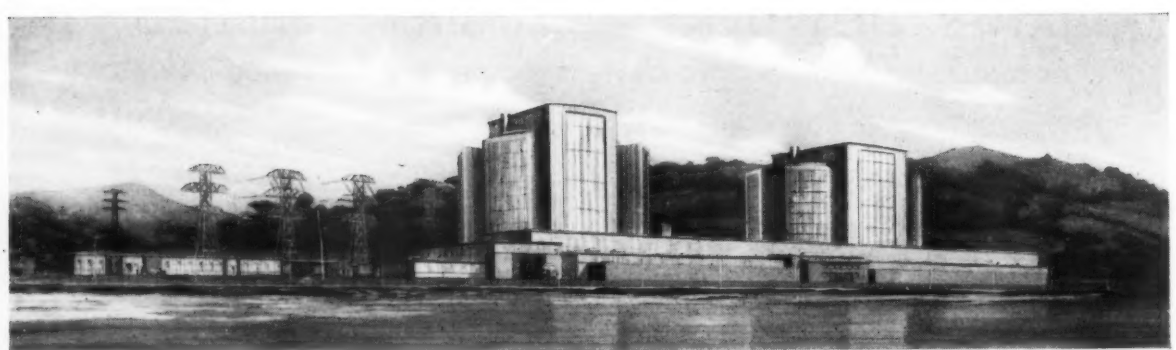
ATOMIC ENERGY GROUP

are proud to announce that they are to build for

The South of Scotland Electricity Board

the largest nuclear power station in the world

Installed electrical generating capacity, 360,000 kilowatts



An artist's impression of the new nuclear power station

Britain leads the world in nuclear power for peace

THE GENERAL ELECTRIC CO LTD • SIMON-CARVES LTD • THE MOTHERWELL BRIDGE & ENGINEERING CO LTD • JOHN MOWLEM & CO LTD.

February 1957
Volume 2
Number 10

Nuclear Power

The journal of British nuclear engineering

EDITOR
William Davidson

CONSULTANT EDITOR
James F. Hill
HARWELL

INSTRUMENTATION EDITOR
Dr Denis Taylor
HARWELL

METALLURGY EDITOR
Prof. J. Geoffrey Ball
LONDON UNIVERSITY

ISOTOPES EDITOR
Dr Alfred Maddock
CAMBRIDGE UNIVERSITY

ADVERTISEMENT DIRECTOR
Harry T. Kane

	Editorial	37
	Worldview	39
	Novel fuel element feature of Scottish plant	42
	Berkeley, the first CEA station to be started	48
	Spherical shell chosen for Bradwell	52
	How the stations compare	54
ALLFORD	Is appearance important?	57
PULSFORD & WASHTELL	Personnel protection instruments for use in gamma irradiation cells	58
	Equipment	62
	Firms cooperated to build Lido	65
	Supplement 4–Lido	facing 66
HILL	Reactor Physics–9	67
	Companies	71
	Institutions	73
	Books	74
	Research reports, Programme, Names	76
	Patents	77
	Index to advertisers	facing inside back cover

Subscriptions to publishers Rowse Muir Publications Ltd. Single copies UK 3/6 plus 7d postage, 5/6 overseas, 75c US and Canada. Per annum £2.2.0 UK, £3.3.0 overseas, $8.0 US and Canada. Post free

The entire contents are protected by copyright in Great Britain and all the countries signatory to the Bern Convention; nothing therefrom may be reproduced in any manner without the written permission of Rowse Muir Publications Limited. Nuclear Power must not, without the consent—in writing—from the publishers, be re-sold, lent, hired out or otherwise disposed of in a mutilated condition or in any unauthorised cover, by way of trade, or annexed to or as part of any other publication or advertising, literary or pictorial matter whatsoever. Special attention is called to the fact that your acceptance of this magazine with notice of the above terms constitutes a contract upon these terms between you and the person who sold it or supplied it

ROWSE MUIR PUBLICATIONS LTD, 3 PERCY STREET, LONDON, W1

A Time for Greatness

Times of crisis are times for greatness. In this country, nuclear power must play its part in meeting the critical shortage of fuel, and therefore the building of a nuclear power station becomes an urgent as well as a thrilling task.

Work began on the nuclear power station at Berkeley in Gloucestershire on January 7th and was planned with all the care of a military operation. The preparation of the foundations for the first reactor has already started and the site from the air looked like a Normandy beachhead. Men and heavy vehicles were moving everywhere, building this great nuclear power station.

A·E·I
John Thompson Nuclear Energy Company Limited

Balfour Beatty and Co Limited

John Laing and Son Limited

Nuclear Power
FEBRUARY 1957 VOLUME 2 NUMBER 10

Flying start

THE SPEED WITH WHICH THE CEA's nuclear power programme has got under way is astonishing and is the clearest possible demonstration that Britain really means business. Added to this, Lord Mills' appointment as Minister of Power shows the importance the Government attaches to this crash programme. The appointment to Cabinet rank of a man who is not a Member of Parliament is not unprecedented but it can rarely have been done before with such thorough justification.

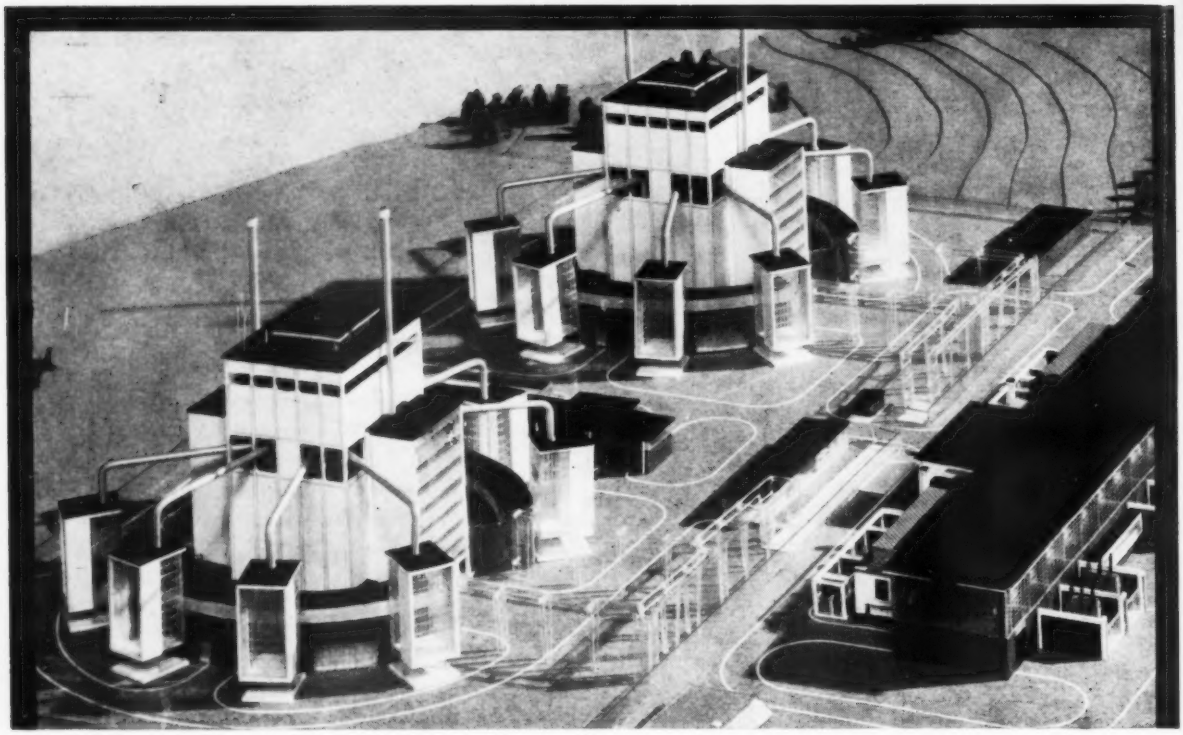
There is little doubt that the 1955 White Paper Plan was a good one in principle. Events have overtaken it and it is now inadequate in scale but as a basis it has proved to be of inestimable value. Full credit should be given to Mr Geoffrey Lloyd for this. In the carrying out of the plan, however, it has been apparent for some time that a Beaverbrook would be needed. While he was at the Ministry of Aircraft Production in 1940-41 Beaverbrook, with his uncivil servant methods made few friends; but he got the much-needed planes. In the early nuclear age, Lord Mills will have the same sort of task and for this he is well qualified, having in fact served under Beaverbrook during those critical years.

As is well-known, one of the tightest bottlenecks is likely to be steel and it was a wise move of Mr Macmillan's to include this in Lord Mills' portfolio. There are many competing demands for this primary raw material and the new Minister's experience in handling this sort of problem in the Allied Control Commission in Germany should stand him in good stead.

The British way of life has always shunned the principle of government by specialists and the few occasions in recent years when it has been adopted—the ex-Minister of Defence is one example—have not been conspicuously successful. Nevertheless, the nuclear programme is something unique, combining the virtues of central planning with a wide measure of free enterprise, and this doubly-exceptional appointment—a non-politician and a specialist—is a bold expedient, the success of which will be watched with interest.

The early stages of the programme are planned—commenced, in fact—and one of Lord Mills' first tasks, after he has ensured that they can be carried out, is to devise the subsequent developments. In this, apart from the obvious ones about reactor types, questions of power station location loom large. At present, almost every site chosen is the subject of a public enquiry and as long as it is thought necessary to build the stations in areas of low population density these are likely to go on, because such locations are precisely those which arouse the bitterest controversy. There is no doubt that nuclear stations of the type we are considering are no more prone to an explosive type of accident than conventional ones, but the fact that it has not yet been thought prudent to suggest a station in an urban or suburban area indicates that doubt still exists as to the question of radioactivity levels. With on-load fuel charging going on daily, transport of irradiated fuel back and forth, periodical blowdowns and possible coolant leaks, the gradual contamination of an area over a period of years is at least a possibility. This, however, is an engineering and administration problem and with skilful mechanical design and strict control of fuelling operations, these fears can be removed.

The present siting policy is correct until some experience has been gained but we cannot wait for four or five years before starting the second round. Experience can, however, be obtained from Calder Hall and no doubt this is being done. What is certain is that we cannot indefinitely continue to ruin the few unspoilt areas in our country; we must soon begin to start building stations in industrial areas.



Nuclear power for Britain

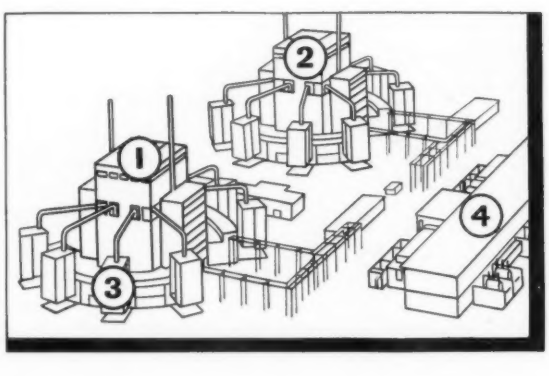
SUNVIC CONTROLS LIMITED are undertaking (on behalf of the A.E.I.—John Thompson Nuclear Energy Company) the design and supply of the reactor and heat-exchanger instrumentation and of the gas-activity monitoring equipment, for the first commercial nuclear power station in the world. This power station is now under construction at Berkeley in Gloucestershire.

SUNVIC CONTROLS LIMITED are also engaged in instrumentation for the three Research Reactors for Associated Electrical Industries Limited, the Atomic Weapons Research Establishment, and the Government of West Germany. The Company are also experienced in other process control fields — notably in the oil and chemical industries.

1 and 2 Two reactors are contained in cylindrical pressure vessels 50 ft. diameter and three inches thick. The nett output of these reactors will be three times that expected at Calder Hall.

3 Steam Raising Plant The heat exchangers, which will be built by the John Thompson Company, will produce super heated steam at two distinct pressures, each bank of boilers feeding dual turbo-alternator sets.

4 The Turbine Hall The one central turbine hall will contain four Metropolitan Vickers' turbo-alternator sets, operating at lower steam temperature and pressure than is usual in more orthodox power stations.



SUNVIC CONTROLS LIMITED

NO. 1. FACTORY · TEMPLE FIELDS · HARLOW · ESSEX *Telephone : Harlow 24231/5. Member of the A.E.I. Group of Companies*

SC/31

UNITED KINGDOM

Berkeley, Bradwell started

With the ink scarcely dry on the contracts, work on Britain's new power stations is already well under way. First off the mark was the AEI-JT group, who, without ceremony, moved into the Berkeley site on Jan 7. First jobs were to obtain access to no 1 reactor site, and erect site offices and labour camp. Work was aided by a new 1½ mile road from Berkeley to the site which the County Surveyor just completed in time. In a week, with 400 men, the hardcore road had reached the reactor site. Here, a 250ft-dia hole 35ft deep is being excavated for the foundations. This is being done by a Lima dragline and two 43RB's, the mucking out being by Euclid rear-dumps. Most of the site is below the Severn flood level and to handle the ground water expected, the site is being dewatered. When finished the site will be filled to 2ft above flood water level. The labour camp is initially for 600 workers with bungalows for married men. No shortage of unskilled men is reported at the moment and buses to the site run from Bristol, Stroud and Gloucester.

The rapid start is due to very careful planning, detailed programmes being prepared in advance for the first 12 weeks. Great enthusiasm is reported from the site where work is proceeding with almost military precision. John Laing & Sons Ltd are in charge of the reactor buildings, while Balfour Beatty & Co Ltd are handling the turbine house and intake works, the construction camp and the access roads.

Three days have passed since ground was broken at Berkeley. Four days later this access road was surfaced and run 500 yards to No 1 reactor site

Work at the other CEA site, at Bradwell in Essex, was begun on Jan 18 when CEA chairman Lord Citrine officially inaugurated operations by driving a bulldozer across the site on the Blackwater estuary. Lord Citrine was accompanied by Mr Robin McAlpine—of the Nuclear Power Plant Co's civil engineers. Speaking afterwards, the CEA chairman stated that he had no doubt that the output of this type of station could be raised to 500MW in a further two or three years. This would mean that the original 12 stations programmed in the 1955 White Paper might not need to be greatly increased since they would be so much more powerful. Referring to Bradwell and Berkeley, Lord Citrine said they were due to be generating by the winter of 1960/61. He hoped that a spirit of friendly rivalry would animate the two groups in the expeditious construction of these stations so that the public may have the benefits of the electricity they will generate, at an even earlier date.

Sir Claude Gibb, NPPCo Chairman, stated that Bradwell would be the first truly economical nuclear power station in the world to go into regular service. He added that allegations that the AEA had not allowed industry to participate in nuclear power developments were not true—they were given the opportunity, but many firms were too busy, or too short of staff: others lacked vision and faith. Pile driving for No 1 reactor started a few days ago and a landing stage is to be built for materials arriving by sea. Some 2,000 men will eventually be working on the site, operations at which are under the control of Mr Andrew Young who, it will be recalled, was resident engineer at Calder Hall.

Still snagged by a public enquiry, the GEC project for the South of Scotland Electricity Board is at present marking time, although far more technical details have been released about it than the other two stations. The enquiry opened on Jan 29 under Sir Randall Philip QC, Sheriff of Perth and Angus. It considered three main items: consent for permission to construct, planning permission and compulsory purchase of the site. Some 34 objections were heard—mostly from the Hunterston area.

At the Bradwell sod-cutting, Lord Citrine (at the controls) receives a model bulldozer from Sir Claude Gibb

New Power Minister

In last month's Cabinet reshuffle following Sir Anthony Eden's resignation, Mr Aubrey Jones left the Ministry of Fuel and Power. In his place, the new Premier Harold Macmillan appointed an old colleague, then Sir Percy Mills, who was associated with him in carrying out the housing programme in 1950-51 when Mr Macmillan was Minister of Housing. The title of the Ministry has been shortened to simply Ministry of Power and its scope has been widened to include responsibility for steel production—hitherto under the aegis of the Board of Trade.

Sir Percy was not a member of Parliament and to enable him to become a Minister he has been created a Baron. He has taken the title of Baron Mills, of Studley in Warwickshire. To represent the new Ministry in the Commons, Mr Reginald Maudling, who was Minister of Supply in the Eden Administration becomes Paymaster-General.

The new Minister was, until his appointment, vice-chairman and managing director of W. T. Avery Ltd, the well-known Birmingham firm of weighing and mechanical testing machines and was also on the Board of Babcock & Wilcox Ltd. He is chairman of the National Research Development Corporation.

Order of Merit for Sir John

Nuclear power figured prominently in the Queen's New Year Honours, announced on Jan 1. The Order of Merit goes to Sir John Cockcroft, Director of the AERE, Harwell. Created Knights Bachelor were: Mr Josiah Eccles, deputy Chairman (ops), CEA and Mr W. L. Owen, Director of Engineering at the UKAEA Industrial Group, Risley. Sir Christopher Hinton, the IG's managing director received the KBE. CBE's went to Dr J. F. Loutit, director of the radiobiological research unit at Harwell; Mr Robin McAlpine, deputy chairman of the Nuclear Power Plant Co Ltd; and Prof W. V. Mayneord, professor of Physics (applied to medicine), University of London. The Order of the British Empire was granted to Dr H. Kronberger, chief physicist at the UKAEA Industrial Group; Dr W. M. Court-Brown, director of MRC research group working on genetic effects of radiation. In the Commonwealth, E. W. Titterton, Professor of Nuclear Physics at Canberra, receives the CMG.

The successful completion of Calder Hall is marked by an award of the British Empire Medal to Mr E. G. Gale, a foreman erector with Strachan & Henshaw Ltd, and the same honour went to Mr P. Legge, a charge hand at the AERE, Harwell.

Duckworth now CEA Deputy Chief

Increased status for nuclear power within the Central Electricity Authority is a feature of new appointments, backdated to Jan 1, announced last month. Mr J. C. Duckworth, hitherto described merely as Nuclear Power Engineer, now becomes Deputy Chief Engineer (Nuclear Power).

The senior appointment is that of Mr J. D. Peattie who becomes Chief Engineer. Mr Peattie has been acting Chief Engineer since Mr V. Pask retired but he is due to retire himself next January when he will be succeeded by Mr F. H. S. Brown. Another appointment is that of Mr E. S. Booth to be Deputy Chief Engineer (Design and Construction). Mr Duckworth, after war time service on radar, went to Chalk River in 1946. He returned in 1947 and went to Harwell where he supervised a group working on neutron spectroscopy involving measurement work concerned with nuclear reactors. He became Chief Engineer of the Ferranti Laboraries, Wythenshawe in 1950 and joined the nuclear power department of the CEA in 1954.

Nuclear heat—Harwell discussion

The possibility of using the heat produced in reactors apart from the generation of electricity, was discussed at a one-day conference held at Harwell on Jan 18. Among those at the conference, to which the press was not invited, were representatives from interested government departments, research establishments and associations and the chemical industry. Harwell director Sir John Cockcroft opened the conference. Papers were presented on: *UKAEA reactor developments* (Dr J. V. Dunworth, AERE, Harwell); *The use of heat on a national scale* (Sir Sidney Frew, Ministry of Power); *Heat use in the heavy chemical industry* (G. Nonhebel, ICI); *Some thoughts on the use of heat from nuclear reactors* (C. M. Nicholls, AERE, Harwell); *Heat interests of the Gas Council* (Sir Charles Ellis, Gas Council); *Heat interests of the National Coal Board* (Dr W. Idris Jones, NCB); and *Large scale distillation of water* (J. Leicester, British Launderers' Research Association).

Hankley, not Inkley

The spot on the south shore of the Bristol Channel chosen by the Central Electricity Authority for its third power station is so remote that even its name is not generally accepted. This was originally designated Inkley Point by the CEA who took it from an Admiralty chart. However, it seems that this is not its local name and in agreement with the local authorities it will henceforth be known as Hankley Point.

FRANCE

Uranium prices disclosed

In Metropolitan France, uranium ore reserves have been estimated at between 50 000 and 100 000 tons. Of this, 10 000 tons have been proved by direct workings or borings, the remainder estimated from geological analogies. In Madagascar, some 1 000 tons of uranothorianite containing 10 to 20% uranium and 60 to 70% thorium have been proved. This deposit is by far the richest of its kind in the world and makes France one of the principal producers of thorium. These figures were released by the CEA in December in time for the Brussels talks on Euratom.

Prices for uranium concentrates announced by the CEA were 12 000 francs per kg of uranium with a further 5 000 francs per kg for the reduction into metal at Le Bouchet factory. Extensions to the factory now in progress should bring these down to about 10 000 francs for concentrates and 4 000 francs for reduction to metal—both per kg of uranium.

The CEA forecasts an output of metal of about 500 tonnes in 1958 rising to about 1 000 tons in 1961.

Training for Scots engineers

The SSEB have launched a programme for training of senior technicians in nuclear power engineering. This is being done in cooperation with the UKAEA and many of the engineers will gain experience at Harwell, Calder Hall, Chapel Cross and Dounreay. Glasgow University has also cooperated on the work and plans are proposed to set up a training centre in Glasgow.

INTERNATIONAL

Too much heavy water!

The AEC announced last month that its heavy water plant near Dana, Indiana, is to be placed in full standby condition by late 1957. The Dana plant, and the other AEC heavy water plant at Savannah River, have been run at capacity since start-up and have now manufactured sufficient D_2O for the initial charge of the Savannah River reactors and for an emergency stockpile.

Forecasts of future heavy water requirements indicate that only one plant will be needed during the next four years. Shutdown at Dana will be slow—it will take place over a period of nine months—to allow maximum recovery of the material in the plant vessels and to assure careful preservation of equipment.

In Canada, the Consolidated Mining and Smelting Co has bought, for an undisclosed price, the heavy water plant at Trail, BC, which the AEC closed early in 1956 because it was too costly.

More funds for H-reactor

The AEC civil programme for the fiscal year beginning on July 1 will account for 3 cents out of each dollar of the $70,807m to be spent by the US Government, according to President Eisenhower's budget message submitted to Congress on January 10. This, however, amounts to over $2,000m. National Defence will account for 52 cents per dollar and it can be presumed that some of this will also be spent through the AEC. Furthermore, the Mutual Security Programme, amounting to six cents per dollar, will also include atomic aid. The President's message said that large-scale power reactors were not the responsibility of the Federal Government and no funds for these are included in the bud-

get. If, however, acceptable proposals for non-Federal reactors do not materialize in a reasonable time, a request would be made to Congress for funds for direct construction by the Federal Government. To encourage industry to invest in nuclear power plants, government legislation is to be introduced to supplement commercial insurance against possible accidents. The AEC will further explore new power reactor concepts and more resources will be put into developing a thermonuclear reactor. To help provide more scientists and engineers, the Budget will provide increased grants for equipment and teacher training and the United States is also to maintain and increase its foreign aid programmes for the development of nuclear power.

AUSTRALIA

Lucas Heights Dido ready soon

The Dominion's first reactor, now under construction at the Lucas Heights research laboratories of the Australian Atomic Energy Commission, is due to be completed next June. This is being built by Head Wrightson Processes Ltd under a contract worth £A937,500. The reactor is virtually identical to the Harwell Dido which was also built by this company. Work on the site—some 20 miles south-west of Sydney—began in October 1955. Graphite and enriched fuel is being supplied by the UKAEA and heavy water by the USAEC. These details of the Australian reactor are given in the AAEC's fourth annual report which covers the year ended June 30, 1956.

On the general power situation, the report notes that Australia's total coal and hydroelectric reserves are ample in quantity to meet all requirements for some decades but they are not always to be found where they are needed. Nuclear power from large central stations is not likely to be competitive for some time, although in isolated areas where conventional fuels are abnormally expensive, medium and low power nuclear plants might prove to be economically useful.

In the field of isotopes, however, there is an immediate opportunity in medicine, agriculture and industry At present these are obtained from abroad but when the Lucas Heights reactor is working, Australia will be producing her own. Mentioned specifically in the report is the possibility of pasteurization of chilled meats by irradiation. The AAEC have set up an Isotope Section under Dr J. N. Gregory who has studied the subject at Harwell and a technical advisory service is now available.

The report admits that, for some time, Australia will have to rely on British and other firms for specialized nuclear equipment but it notes that already in Australia there are firms capable of carrying out some portion of the work and the Commission is encouraging more firms to enter the field. A considerable part of the report deals with uranium prospecting and mining.

LETTERS

Sir, It has come to our notice that some firms who have undertaken work for the United Kingdom Atomic Energy Authority, and who, as a result of advertisements and other notices in "Nuclear Power", are receiving enquiries from abroad, are under the impression that the terms of their contracts with the Authority prohibit them from dealing with these foreign enquiries.

I wish to make it clear that the Atomic Energy Authority are most anxious to encourage export trade in the nuclear field, and would welcome the opportunity of discussing with any manufacturer the possible exploitation of all his products which are based on designs arising from development contracts placed by the Authority. Subject to the need to safeguard militarily secret information in cases where this consideration is present, the Authority are ready to consider terms on which information may be given to third parties.

May I suggest therefore that firms who receive enquiries about products based on such designs should consult Mr W. P. Warren, Commercial Manager at the Authority's Industrial Group Headquarters, Risley, Warrington, Lancs.

Yours etc,

Eric H. Underwood,
Director of Public Relations,
UKAEA

Jan 22, 1957

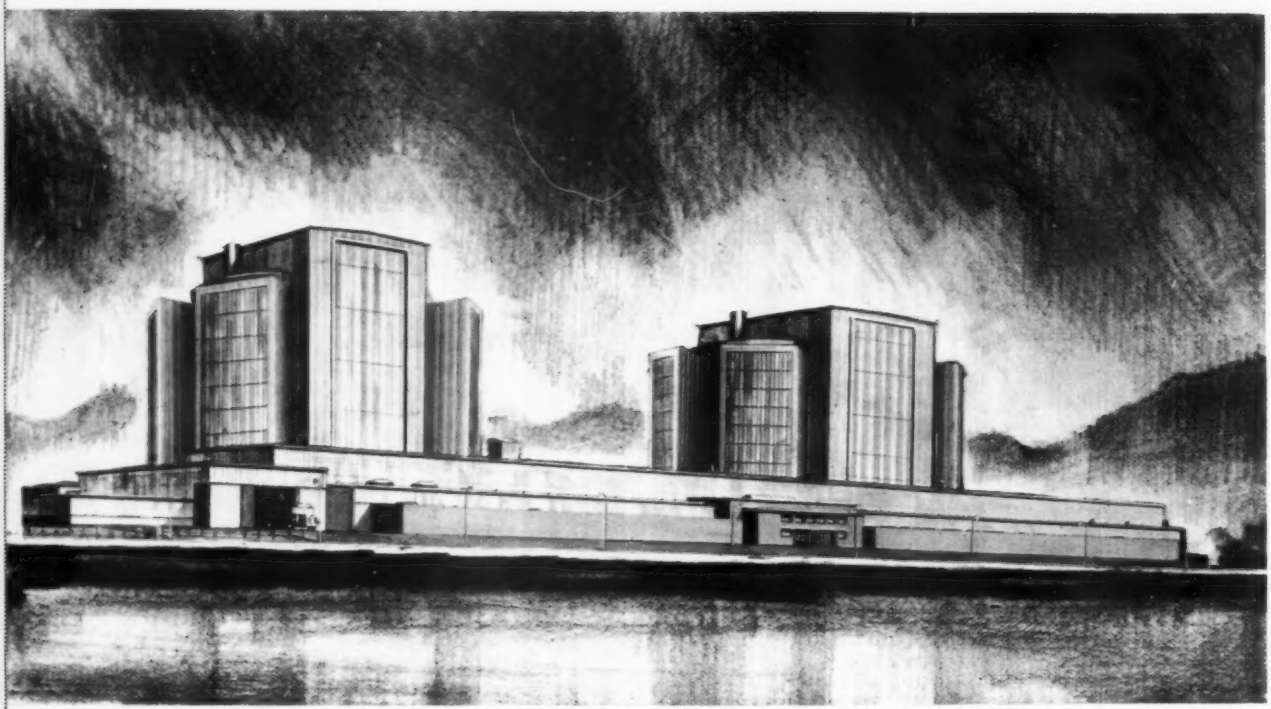
In this issue . . .

LES ENTREPRISES BRITANNIQUES d'électricité ont annoncé le 13 décembre la signature des contrats pour la construction de trois stations électriques nucléaires. A la différence de Calder Hall et de trois stations identiques construites à present pour l'Administration de l'Energie Atomique au Royaume-Uni, ces stations nouvelles sont destinées en premier lieu pour la génération d'électricité. Tout en étant basées en principe sur la formule heureuse de Calder Hall, elles vont avoir un rendement de puissance net quatre fois plus grand. Le facteur le plus important qui a mené à ce perfectionnement est l'augmentation de l'épaisseur de la cloche à pression de 5,1 mm à 7,6mm. Ceci a permis d'augmenter les noyaux centraux ainsi que la pression des réfrigérants gazeux.

LA COMISION DE ELECTRICIDAD DE LA GRAN BRETANA anunció el 18 de diciembre último la concesión de tres contratos para centrales electroatómicas. A diferencia de Calder Hall y de otras tres centrales exactamente similares que están siendo construidas para la Comision de Energía Atómica, estas nuevas estaciones han sido diseñadas principalmente para la generación de electricidad. Aunque basadas en principio en la satisfactoria fórmula de Calder Hall, las nuevas estaciones serán capaces de una producción neta de energía cuatro veces mayor. A este mejoramiento ha contribuido principalmente el casco de presión, que tiene ahora 7,6 cm de espesor en lugar de 5,1 cm. Esto ha conducido a núcleos mayores y a presiones más altas del gas enfriador.

DIE ELEKTRIZITATSFIRMEN GROSSBRITANNIENS haben am 13. Dezember die Unterzeichnung von Verträgen betr. Bau von drei Kernenergiezentralen bekanntgegeben. Im Gegensatz zu Calder Hall sowie den drei genau identischen Zentralen, welche jetzt für die Atomenergiebehörde gebaut werden, sind die neuen Stationen in erster Linie für Elektrizitätserzeugung bestimmt. Der Grundgedanke ist zwar derselbe wie der in Calder Hall erprobte, doch haben die neuen Zentralen eine etwa viermal grössere Nettoleistung. Der wichtigste dazu beitragende Faktor ist die Verstärkung der Druckglockenwände von 5,1 cm bis 7,6 cm. Dieser Umstand ermöglicht es grössere Reaktorkerne und höhere Kühlgasdrucke anzuwenden.

ВЕЛИКОБРИТАНСКИМИ ЭЛЕКТРИЧЕСКИМИ ПРЕДПРИЯТИЯМИ сообщено 13 декабря о заключении контрактов на постройку трех ядерных силовых станций. В отличие от Колдер Холла и трех совершенно таких-же станций, строящихся для Управления Атомной Энергией, эти новые станции предназначены главным образом для генерирования электричества. Хотя конструкция новых станций в принципе согласуется с формулой, успешно испытанной в Колдер Холле, их мощность будет вчетверо больше. Крупнейшим фактором, обусловливающим этот прогресс, является увеличение толщины корпуса высокого давления с 5,1 до 7,6 см. Это обстоятельство делает возможным увеличение активной зоны и давления охлаждающего газа.



Planned for a site on the Firth of Clyde, the exact location of the South of Scotland Electricity Board's station has not yet been approved

NOVEL FUEL ELEMENT FEATURE OF SCOTTISH PLANT

THE REACTOR GRAPHITE STRUCTURE is built up of accurately machined bricks and tiles to form a cylinder (actually a 28 sided section) 50 ft 6 in. in diameter and 28 ft high, weighing nearly 2 000 tons. The reflector has an average thickness of 3 ft at the sides and 2 ft 6 in. at the top and bottom. In the core proper there are 3 288 vertical fuel channels arranged in the form of a square lattice with a pitch of 8¼ in.

The neutron flux distribution is flattened by inserting neutron-absorbing stainless steel rods into a number of the central core channels. As fuel is burned up, the absorbing material is gradually removed and the flattening is finally achieved by using depleted uranium in the centre of the core. In this way a higher burn-up of the central fuel elements is attained. The maximum neutron flux in this region is approx $2{\cdot}5 \times 10^{13}$ neutrons/cm^2/sec. In the outer core region, the moderator channel diameter is reduced which, by reducing the mass flow of coolant, keeps up the temperature of the fuel can, and, therefore, of the outlet gas.

Control of gas temperature is achieved by 'gagging.' Steel plates with central holes of varying diameter are mounted at the bottom of certain fuel channels outside the flattened region, which restricts the flow of gas up these channels.

Replaceable channels

The fuel consists of pure natural uranium metal. Each element is a cylindrical rod 1·15 in. in diameter and 24 in. long. The cans are of magnesium alloy with extended surfaces in the form of fins. Ten elements constitute the complete charge for one vertical channel, and an entirely novel method has been developed for their support—*the GEC Replaceable Channel Fuel Element.*

The essential feature of this is that each canned fuel element is individually supported and located by non-metallic 'spiders' inside a relatively large bore graphite tube.

The assembled fuel elements, each consisting of a fuel cartridge and a graphite sleeve, can be mounted one on the other within the fuel channel and thus

achieves the combination of separate support and end-to-end stacking. Location of the tubes centrally in the main moderator channels is by small graphite lugs on the tubes and by a 'cup and cone' arrangement of successive tubes.

The main gas flow is up the bore of the graphite tube in direct contact with the fuel elements, but a small quantity passes up the annular space between the graphite sleeve and the main channel to extract the heat (about 6% of the total) generated by collision processes in the graphite itself.

Other important advantages of the *replaceable channel fuel element* are:

1. The smooth external shape of the graphite cylinder gives less abrasion of the main channel during loading.
2. If CO_2-graphite reactions occur, the affected graphite can readily be replaced.
3. Without the replaceable channel, a bad can burst could lead to fission product contamination of the main moderator channel; with this system, the contamination will be discharged with the faulty element and the moderator channel can continue to be used.

Inner shell

The reactor core rests on support plates on a 7 ft-deep 'egg-box' steel grid which is in turn supported on a steel skirt. On top of the grid rests a thick steel plate providing an accurately levelled surface for the erection of the core structure. The core is surrounded by an inner shell in the form of a domed cylinder, open at its lower end. Completely enclosing the core, grid and inner shell, is a spherical pressure vessel 70 ft in diameter.

Carbon dioxide at a pressure of 150 lb/in^{2}g will be blown into the outer spherical vessel via eight 5 ft diameter ducts situated at 'equator' level. The cool gas then passes downwards between the outer and inner vessels, and upwards through the support grid and the core channels.

The inner vessel is made of a silicon-killed mild steel boiler plate and has to withstand only the pressure drop across the core of 4 lb/in^2.

Steel for the sphere involved consideration of:

a. resistance to deformation by creep at the operating temperature
b. resistance to failure by brittle fracture
c. weldability

Fine-grained aluminium-killed steels meet the requirements of b and c, but their creep resistance is only about half that of silicon-killed boiler plate. This is the reason for the double-shell construction: the outer, pressure-resistant sphere will be made of *Coltuf 28*, made by Colvilles Ltd, and the relatively thin inner shell, of creep-resistant silicon-killed boiler plate.

The sphere will thus withstand the gas pressure of 150 lb/in^{2}g without being subjected to the maximum gas outlet temperature of 745°F. In fact, under normal running conditions no part of the sphere will be at more than 450°F which is well below the creep range of the material.

Double biological shield

Completely surrounding the reactor is a concrete biological shield. At the base of the reactor this is 6 ft thick, increasing to a total of 9 ft at the sides, while the roof shield is 10 ft 6 in. thick.

The 9 ft side shield is split into two parts on two arcs between the core and the heat exchangers, yielding 'blimps' in which the gas coolant ducts are contained. The inner walls of the blimps are 4 ft thick and the outer ones 5 ft thick. The shielding is also locally thickened opposite the cold ducts in the inner wall.

On-load fuelling

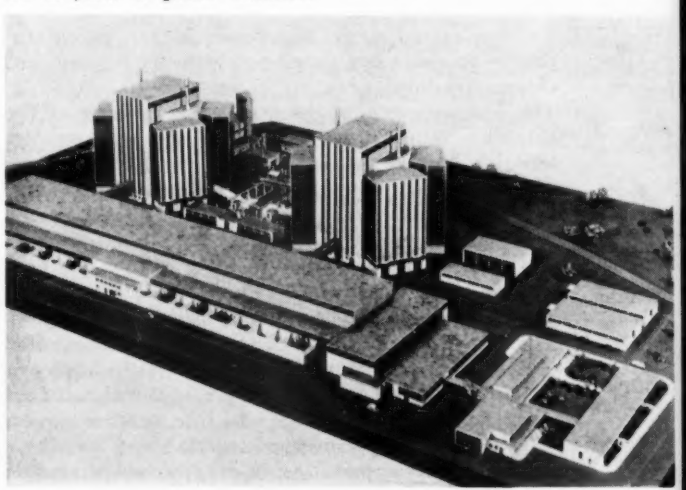
The entire fuel charge and discharge operations for each reactor are carried out by a single multi-purpose machine working in a shielded chamber below the reactor. All operations can be carried out under pressure and while the reactor is on load. At no time during fuelling does the controller see the machine (except through television monitor screens), all movements being remotely controlled from a room in the reactor building.

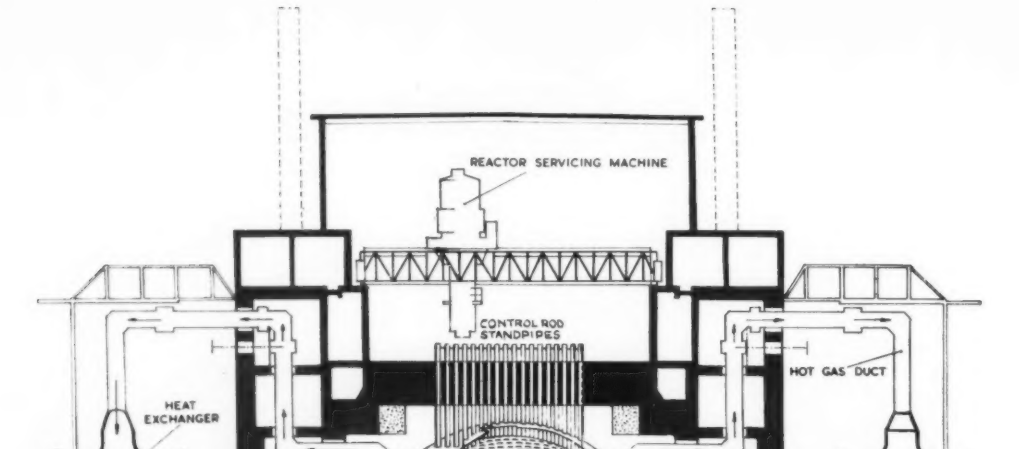
The 3 288 fuel channels are divided into 'charge groups' of 36. The channels are continued downwards through the grid by 'fixed channel tubes.' In any one charge group, the fixed channel tubes are bent inwards into gentle curves so that their open lower ends can be fed from a point below the centre of the group. Vertically below this centre line is a standpipe for each charge group—101 in all. Thus through each of these 101 standpipes any one of 36 fuel channels in a charge group can be reached by the charge machine.

The standpipes project upwards through the spherical shell and downwards to a point just below the biological shield forming the roof of the circular charging chamber. The lower ends of the standpipes are sealed with a steel door protected by a concrete shielding plug.

The charge machine vessel is approximately cylindri-

Model shows fuel chutes leading from reactor fuelling bay to cooling pond. Heat exchangers are in pairs, in glazed enclosures





Outstanding in the three designs, the GEC plant fuels from below. Upper standpipes are for control rods and other channel services such as absorbers

cal, 30 ft high, capable of withstanding the full gas operating pressure, and seated on a 4-wheeled carriage. The wheels run on tracks mounted on a turntable spanning the diameter of the charging chamber. Thus by rotation of the turntable and movement of the carriage along it, the nozzle in the top of the charge machine can be aligned directly beneath any chosen standpipe.

The first operation of the machine is to move off the turntable into the loading bay in the main reactor building. Above this is the charge preparation room where the components of the replaceable channel fuel element are assembled under clean conditions. Five fuel elements, together with a support device and empty graphite tube are lowered into one tube of a 'magazine tube pair' which consists simply of a long open-ended cylinder of polished stainless steel. The empty graphite tube ensures that the lowest fuel element is in the moderator section of the core and not in the surrounding reflector area below. Five more elements are then lowered into another similar tube, the two being strapped together and forming a 'magazine tube pair' containing a complete fuel element charge for one channel. The pair of tubes is then guided downwards through a hatch in the charge preparation room floor into the opening in the top of the charge machine. This process can be repeated if necessary until several pairs of tubes are supported in racks within the machine.

The loaded machine is now driven back on to the turntable and the nozzle positioned below the required standpipe.

Clearance between the top of the charge machine nozzle and the bottom of the standpipes is about 3 in. This clearance is taken up by raising the whole machine on four synchronized electrically-operated jacks until the surfaces abut. The flanges on the two nozzles are then clamped together over an 'O' ring by eight CO_2-operated piston clamps situated radially round the nozzle.

The charge machine is now in position ready for whatever operation it is desired to carry out. Under normal reactor running conditions the sequence of operations would be the removal of one column of 10 fuel elements from a fuel channel followed by the charging of 10 fresh elements into the channel.

Discharged elements are retained within the machine during the re-charging process and are later removed for separation of the graphite sleeves from the fuel cartridges, the latter being stored in the cooling pond. There are two other functions which the charge machine will be expected to fulfil:

a. Axial Inversion

This consists of removing partially irradiated elements, and re-inserting them in a different order so that those which have been highly irradiated in the centre of the core are now positioned at the ends.

b. Group Charge and Discharge

This enables several channels out of the 36 in any one charge group to be charged at one setting of the charge machine. This would be done if it were desired to charge the fuel elements in batches; *e.g.* after a change in fuel element design, but it would be carried out under shutdown conditions.

Cooling irradiated fuel

The cooling pond is situated between the two reactors and serves both. It is 186 ft long by 53 ft wide with a depth of 18 ft. At the termination of each conveyor duct is a heavily shielded concrete block house, and between these on opposite sides of the pond is a concrete wall. The pond is thus divided into two unequal sections, the larger for storing normal cartridges and the smaller for elements from channels in which a burst has occurred.

Frequency controlled rods

There are altogether 208 control rod channels each of which is associated with 16 fuel channels. In practice, not all of these will contain rods. Access to the channels is from above, through 208 stand pipes leading down to the core. Where control rods are fitted, the actuating mechanism is contained in the standpipe.

Control rod drive is by a flexible stainless steel wire rope wound on a conical drum driven by a low frequency permanent magnet motor. Each rod is moved in or out by applying a 3-phase l.f. supply to the motor stator; the rods are held out of the core by reducing the frequency of the supply to zero. *i.e.* a d.c. condition.

The rods—21ft by 2in. dia—consist of a lightweight boron-containing material canned in a thin stainless steel sheath. Short lengths assembled in this way are then placed within the main control rod tube. There are four groups of rods—two coarse groups, capable of a combined reactivity control of 4.85 per cent, one fine group controlling 0.4 per cent, and one safety group controlling 1.25 per cent of reactivity.

A reactor servicing machine in the form of a travelling pressure vessel is situated above the upper biological shield. Its primary purpose is to enable planned maintenance operations to be carried out on the control rods and mechanisms while the reactor is working. The machine can be positioned over any one of the 208 upper standpipes by longitudinal and cross travel motions as in a conventional travelling crane. From this setting the servicing machine can also communicate with any of the sixteen fuel channels served by each standpipe. The machine is also designed to carry out a number of other operations of an emergency nature. *e.g.* recovery of control rods after a cable break, freeing of jammed fuel elements by CO_2-operated hammer, insertion of thermocouple fuel elements, cutting of thermocouple leads so that element can be discharged normally, handling television inspection camera, emergency removal of fuel elements through the top, and servicing of the 16-way gas sampling selector valves which are inside the standpipes.

Burst slugs

Burst slug detection is by successive sampling, in groups of four, of the gas from the 3 288 fuel element channels throughout the reactor. Any solids in the sample are filtered out and the daughter products of gaseous fission products are electrostatically precipitated. A permanent record of each sampling operation is automatically charted and a comprehensive system of alarms indicates in the central control room, not only a burst slug but also any fault in the equipment itself.

Steam raising

Associated with each reactor are 8 heat exchangers, grouped in pairs. The design of these had to take into account:

1. The high pressure of the gas—150 lb/in^{2}g.
2. The low temperature difference available for heat transfer between the gas and the water/steam
3. The high degree of cleanliness required in the parts of the plant exposed to the circulating gas

The unit designed by Simon-Carves Ltd to satisfy these requirements consists in principle of two water tube boilers (high pressure and low pressure) contained within a vertical cylindrical pressure shell.

The heat exchanger shell is of welded construction, 19ft 6in. diameter internally and 73ft 6in. high overall, and will be fabricated and erected by the Motherwell Bridge and Engineering Co Ltd. It is self-supporting and stands on a cylindrical support and base ring. The gas flow is downwards across banks of self-draining multi-loop tube elements which form the economizer, evaporator and superheater sections of the boiler. Individual tube elements are connected in parallel by headers outside the pressure shell. The temperature difference between inlet (750°F) and outlet (400°F) is relatively low and the area of heat exchange surface required is large compared with fuel-fired plants of the same output. Close-pitched small diameter mild steel tubes with an extended surface in the form of fins are used. In all the evaporator and economizer banks the fin will be a mild steel spiral welded to the tube but the superheater tubes will simply have two longitudinal strip fins top and bottom.

Gas ducting

Over 5 000 lb/sec is the coolant flow per reactor and the gas ducts are 5ft in dia.—of boiler-quality carbon steel plate. The runs of ducting are divided into four separate sections connected by flexible bellows at the hinges. Each section is on constant-load supports.

Rapid-closing isolating valves are incorporated in the gas circuits at the reactor inlets and outlets; under fault conditions the circuit can be quickly isolated from the rest of the plant without shutting down the reactor.

The gas circuits also incorporate by-pass filter circuits to keep down the level of dust formed by possible corrosion or erosion of the plant, by-pass drier circuits to remove any moisture introduced into the gas, and CO_2 storage plant and filling system.

Centrifugal blowers chosen

One gas circulator is situated in the base of each heat exchanger and handles the gas at the lowest temperature.

The pressure losses in the coolant system are high and the circulators have to develop a pressure rise of several lb/in^2. But the pressure level in the system is high and the compression ratio is therefore low. To meet these requirements a centrifugal machine was chosen in preference to an axial flow one since more experience was available on the design of impellers of the size required.

The impeller, with backward curving vanes, is mounted on a vertical overhung shaft at the base of the heat exchanger which is large enough for impeller, diffuser and inlet fairing, thus avoiding the need for a special pressure casing. The whole unit, comprising impeller, shaft, seal, bearings, drive and cooling system is suspended from a flange on the pressure shell, care being taken in the mounting to prevent the transmission of vibration to the shell.

The blowers are to be driven by 2 200 h.p., 1 000 rev/min tandem-armature d.c. shunt motors supplied through transformers and 12-phase steel tank mercury arc rectifiers having grid control by individual phase shifters. The phase shifters may be clutched together to give a ganged control of any number of circulators.

Dual-pressure steam cycle

A double pressure steam cycle has been adopted. This supplies steam to a pass-in turbine in which the low pressure steam is admitted to the turbine at an intermediate stage of the expansion. This has the effect of improving the turbine efficiency and the steam dryness at the turbine exhaust and obtaining the advantage associated with the reheat cycle used in fuel-fired plants.

Steam from the heat exchangers is carried on a pipe bridge to the turbine hall situated behind the two reactors. This contains six dual pressure GEC 60MW cmr turbo-generator sets, with hydrogen-cooled alternators.

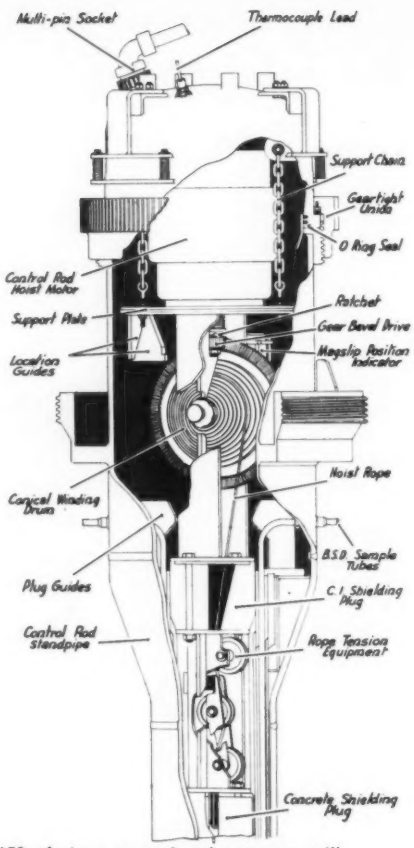
The turbine design follows the general features of the conventional GEC 60MW unit, but incorporates new design features developed for the company's 120MW and 200MW reheat turbines.

Control and instrumentation

A comprehensive system of manual controls and instrumentation for the two reactors and their associated plant is provided in a central control room situated in the turbine building.

The station load is set by the power generated in the reactors, and all deliberate changes are initiated at one or both reactors, certain automatic features being incorporated. The method of overall control between 25 per cent and 100 per cent full power involves coordinated variation of the neutron flux density, the coolant gas flow and the steam flow. Two separate closed loop circuits are incorporated, one for stabilization of reactor power operating on four fine control rods, and the other for stabilization of the total coolant gas flow operating on the circulators. These are termed respectively, *the automatic flux regulator* and *the automatic flow regulator*. The two circuits are combined to the extent that settings of desired neutron flux and desired coolant flow are coupled in a single control known as the *automatic power control* which is motorized (to limit the rate of change of power) and set by the reactor operator at his control desk. A constant ratio is maintained between desired neutron flux and desired coolant gas flow (subject to manual trim). With this system, there is only a small variation with power level of temperatures in the coolant circuits.

The automatic flux regulator adjusts reactivity to compensate for xenon poison transients following deliberate changes in power level, and also maintains a stable power level during 'on-load' maintenance operations, such as replacement of control rods, which affect the net reactivity.



About 150 of these control rod actuators will be used. Actuation is by frequency-controlled motor and conical drum. In emergency, movement is by gravity with controlled braking by permanent magnet

The automatic flow regulator maintains the desired value of total coolant flow in the event of failure of one circulator by temporarily overspeeding the remaining circulators.

When the operator adjusts the desired power by means of *the automatic power control* the resultant changed flow of coolant results in a change in heat flow in the steam raising units. Steam pressures are thus affected, and pressure regulators associated with the inlet valves to each turbine automatically adjust the steam flow to maintain constant pressure conditions. Each steam raising unit has a simple form of automatic feed water control operating from drum level.

It is estimated that a power reduction from 100% to 33⅓% full power is capable of being almost entirely carried out in a controlled manner in under 30 minutes by means of the automatic features provided. As excess steam is blown off in the event of one or more turbo-generators tripping out, rapid decrease of power without having recourse to reactor shut-down is obviously desirable to avoid excessive loss of feed water.

Each turbine is fitted with a governor speed control but in operation this is normally overridden by the pressure regulator. The usual emergency overspeed trip is provided.

Safety arrangements

Despite the adequate information available to the control staff, abnormal conditions may not be noticed immediately and a large number of alarms, both aural and visual, urgent and not-so-urgent, are incorporated.

An unsafe condition is arranged to trip out automatically a section or sections of the station. As this must be done as a last resort, particularly where the reactor is involved, the equipment associated with each of these trips is made as reliable as possible, the more particularly because should it develop an internal fault it must 'fail safe.' To reduce the risk of trips due to internal equipment faults in the particular case of excess neutron flux detection, three detectors are employed, any two of which must operate before the reactor is tripped.

Fuel
Material—Natural uranium rods
Dia. of rod—1·15 in.
Length of rod—24 in.
Rods per channel—10
Rods per reactor—32 800
Uranium per rod—7·64 kg (16·8 lb)
Uranium per reactor—251 tonnes

Moderator and reflector
Core dia.—44 ft 6 in. (50 ft 6 in. with reflector)
Core length—23 ft 0 in. (28 ft 0 in. with reflector)
Total no of fuel channels per reactor—3 288
No of control rod channels per reactor—208
Dia. of control rod channels—3·5 in
Type of lattice—square, 8¼ in pitch
Total wt. of machined graphite per reactor—2 150 tons
Graphite support—Steel plate on 7 ft deep steel grid

Nuclear data
Max thermal neutron flux—$2·0 \times 10^{13}$ neutrons cm^2/sec. app.
Method of flattening—Steel bars replacing fuel elements
Built-in excess reactivity at start-up (cold)—4·57% in k
Average initial conversion factor—0·800

Pressure vessel
Material—Coltuf 28
Shape and dimensions—70 ft i.d. sphere
Thickness of shell—General 2⅜ in
Support course 3 in
Maximum internal working pressure—150 lb/in^2g
Wt. of gas in vessel under operating conditions—41·4 tons
Maximum shell temperature—450°F

Control rods
Material—Boron-containing inserts canned in thin stainless steel sheet and packed in tubular stainless steel control rods
No of rods per reactor—150
Dimensions of rod—Length 21 ft 0 in.
Diameter 2 in.
Wt of rod—70 lb
Control Rod Grouping—Shut-off group 1·25% in k
Fine control group 0·40% in k
Two coarse group 4·85% in k
Total Reactivity controlled—6·5% in k

Biological shield
Material—Reinforced concrete
Thickness—9 ft 0 in. walls, 10 ft 6 in. roof
Shield cooling—Once-through forced and induced draught air cooling, air flow being directed over or through concrete walls

Reactor design performance
Gas temperature at reactor inlet—240°C (400°F)
Bulk gas temperature at reactor outlet—396°C (745°F)
Gas pressure at reactor inlet—150 lb/in^2g
Gas pressure at reactor outlet—145·8 lb/in^2g
Mean fuel rating—2·11MW/tonne
Total gas flow rate—5640 lb/sec
Heat transferred to gas from reactor—530MW
Heat transferred from gas in SRU's—540MW

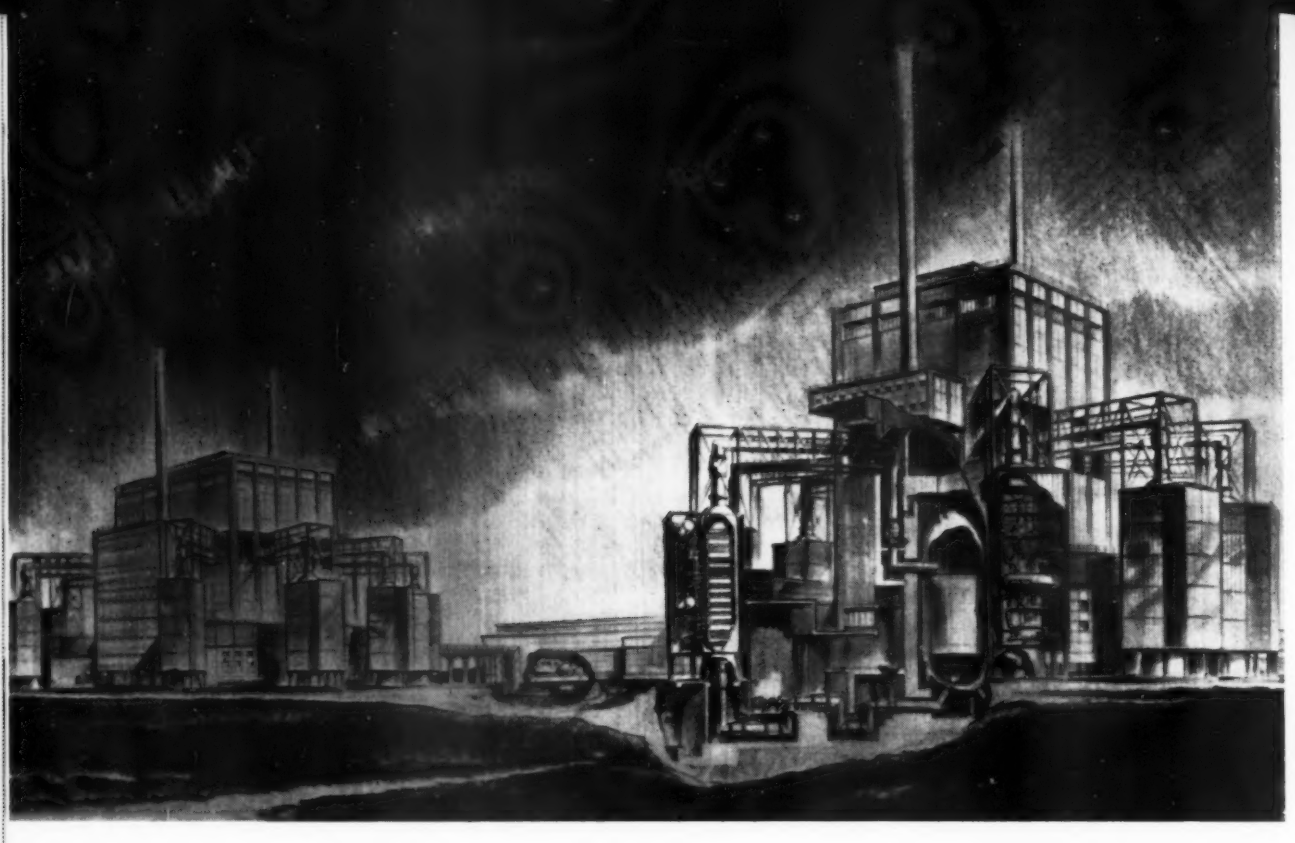
CO_2 system
Main circulators
Type—Vertical shaft, centrifugal
No per reactor—8
Drive—D.C. motors supplied from grid-controlled rectifier
Outlet gas pressure—150·5 lb/in^2g
Gas pressure rise across circulator—7·5 lb/in^2
Circulator input—2 190 B.h.p.
Electrical power consumption per reactor—12·6MW
Running speed—1 000 rev/min
Method of speed control—Grid-controlled mercury arc rectifier
Range of speed control—10:1

Main ducts
No of ducts per reactor—8 inlet, 8 outlet
Duct diameter—5 ft
Gas transit time round circuit—23 sec

Steam raising units
No per reactor—8
Gas volume—18 000 cu ft per boiler
Wt of gas under operating conditions—5·2 tons per boiler
Inlet gas temperature—396°C (745°F)
Outlet gas temperature—200°C (392°F)
h.p. Steam flow—143·1 klb/hr
h.p. Steam pressure 575 lb/in^2g
h.p. Steam temperature 700°F
l.p. Steam flow—69·5 klb/hr
l.p. Steam pressure—145 lb/in^2g
l.p. Steam temperature 670°F

Turbo-generators
No of sets per station—6
Type—Multi-stage, axial flow, impulse-reaction
Continuous maximum rating per set—60MW
Cooling—hydrogen at 30 lb/in^2g
Speed—3000 rev/min
Generator voltage—11·8 kV
Power factor at CMR—0·8
Steam pressure at h.p. stop valves—555 lb/in^2g
Steam pressure at l.p. stop valves—135 lb/in^2g
Steam temperature at h.p. stop valves—690°F
Steam temperature at l.p. stop valves—660°F
h.p. Steam flow per set—382 klb/hr
l.p. Steam flow per set—186 klb/hr
Final feed temperature at CMR—296°F

Steam dumping equipment
Two condensers per station, operating at atmospheric pressure, with spray de-superheaters. Steam released to dump through automatic pressure controlled valves.

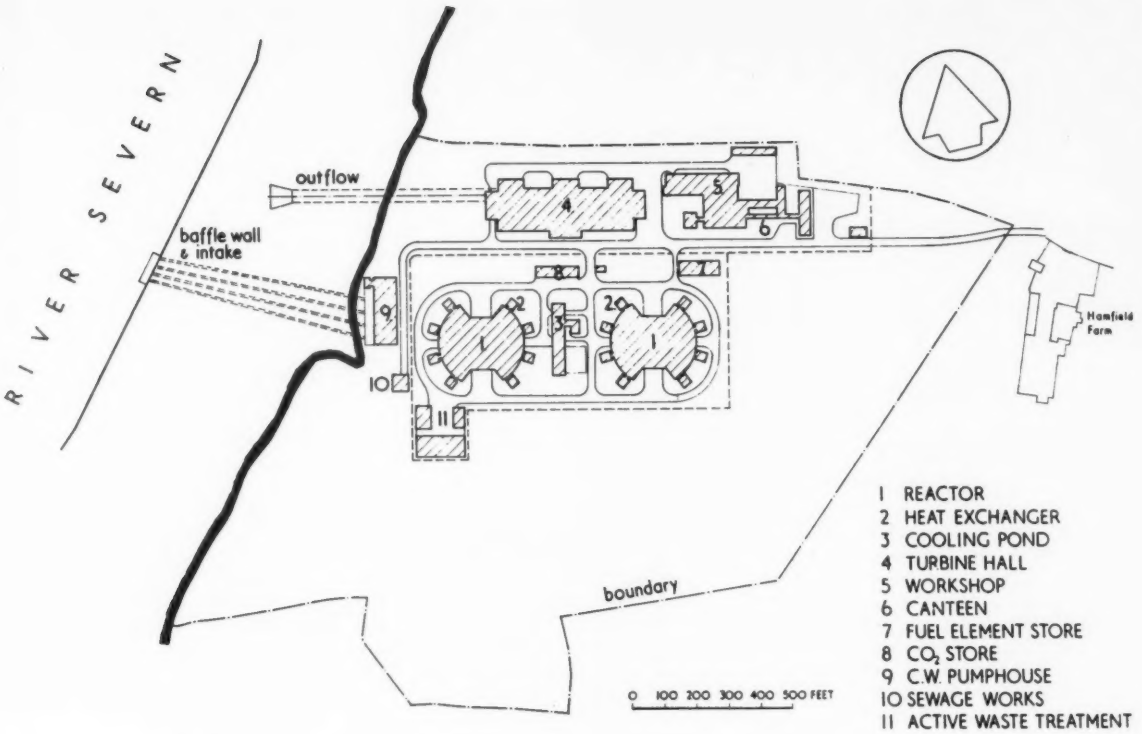


Following the Calder Hall prototype more closely than the others, the output is nevertheless over three times that of its predecessor

BERKELEY, THE FIRST

THE STATION OBTAINED by the AEI-John Thompson group is at Berkeley, on the left bank of the Severn near the railway bridge. The site covers some 96 acres and the plant will have a guaranteed output to the Grid of 275MW. It is likely that the actual output will be very close to 300MW.

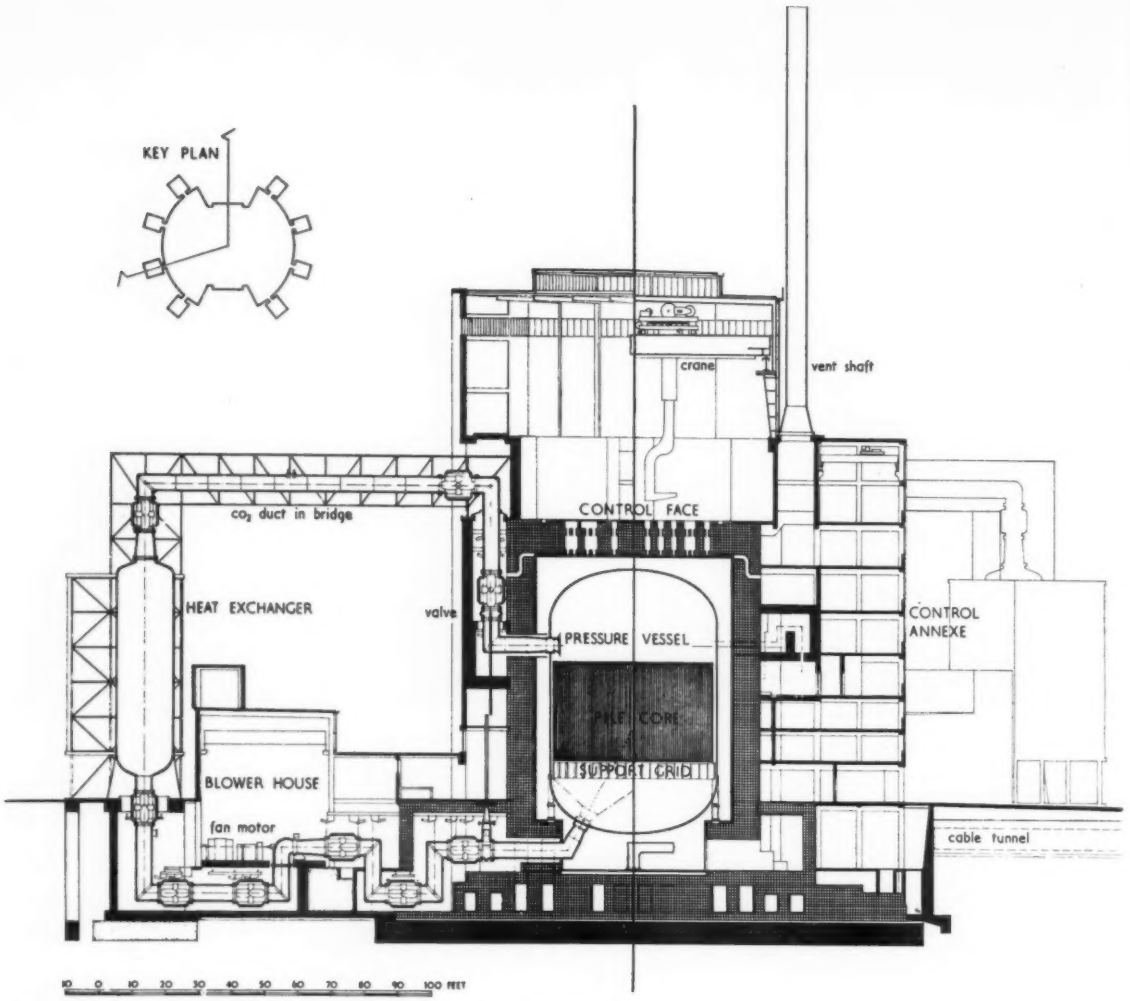
As in the other stations, there are two reactor buildings but these are quite separate and the eight steam-raising towers for each reactor are grouped radially at some distance from the buildings, each one being housed in a glazed enclosure. The core is 48ft dia. and 30ft high and it contains about 3,000 vertical fuel channels. The graphite structure—a 30ft-high, 32-sided prism—is built from individual vertical columns of machined graphite blocks, each supported through a ball-bearing assembly on the cross braced grid. Provision is made for Wigner growth and thermal expansion and equipment is included for initiation and control of periodical Wigner energy release operations. The geometry of the graphite structure is preserved by side restraints in the form of flexible bracelets. The top of the core is capped by cast iron charge-pans as at Calder. These protect the fuel channel entrances and provide locations for the gas sampling pipes. The fuel elements are uranium rods in finned magnesium alloy cans. The elements will be short and will be individually supported in the channels. This is designed to overcome the cumulative effects of creep which can occur with stacked elements. The core is contained in a cylindrical pressure vessel 50ft dia. and 80ft high made in 3in. steel plate. The ends are ellipsoidal and the general arrangement is very similar to that used at Calder Hall except that there is no inlet manifold at the base of the shell, the gas inlets entering the shell directly. The core weight is taken from the grid through the pressure shell to specially designed rocking feet which take up thermal movements. The static gas pressure is 125 lb/in^2. This shell will be fabricated in sections at the Wolverhampton works of John Thompson Ltd and welded on site. Thermal shield plates 4in. thick will also be made at Wolverhampton. Loading of fuel elements takes place from the top, and a travelling gantry is used for placing the charge/discharge machines over the fuel charging ports. These machines are heavily shielded and no parts



Berkeley site plan shows disposition of units and circulating water arrangements. Active area fence surrounds reactors; turbines and non-nuclear plant are outside

CEA STATION TO BE STARTED

of the fuelling gear are left permanently in the pressure vessel. The guides and moving parts are designed with simplicity and robustness as the main features. Irradiated fuel is carried in shielded coffins to the cooling pond where it is stored to 100 days before shipment to the UKAEA's reprocessing plant. Thermal shield cooling is provided by induced draught fan in a manner very similar to the Calder arrangement and the hot air is discharged after filtering through two 240ft-high stacks. The fuel element discharge chute will also be ventilated by this system. The ventilation system has been designed in accordance with the ICRP recommendations (Dec 1954 edition). The main biological shield is reinforced concrete 8ft 6in. thick. The top shield will measure 11ft thick, but due to standpipe voidages, the effective thickness will be 8ft. The main gas ducts, 5ft in dia. are of mild steel, designed, manufactured and tested in accordance with BS 1500, severe duty, where applicable. Flanged joints are reduced to the minimum, circumferential butt welding being preferred because of the minimisation of leakage risk. The outlet ducts pass through the concrete biological shield horizontally, run vertically upwards and then cross horizontally to the steam-raising towers on pratt-truss pipe bridges. On leaving the base of the exchangers the ducts run to the axial-flow blowers which are arranged in a radial layout thus ensuring that the whole duct run lies in one vertical plane. In the gas circuits, to limit the cumulative accumulation of entrained particles, a proportion of the flow is continuously bypassed through cyclones and ceramic filters. Drying equipment will also be installed too in the bypass to keep the humidity below the tolerance level. Blow-down pipework and filters are included to permit any section of the gas circuit to be discharged safely to atmosphere through the stacks. Before a unit is put back into service, it will be purged of air by exhausters. The gas system also include CO_2 storage and charging facilities. The circulators—of British Thomson-Houston manufacture—will be driven by 3,000 h.p. a.c. squirrel-cage induction motors through variable speed hydraulic couplings controlled by electro mechanical actuators. A small d.c. motor supplied from the emergency generating system will be geared to the blower drives



Axial-flow blowers are placed in the cool side of each heat exchanger. On-load fuelling is carried out from above, as at Calder Hall

to provide circulation in case of a major a.c. failure. Switchover will be automatic. The lubrication system is divided into two parts—the gearing and fluid couplings: the blower seals and bearings. Oil cooling will be by distilled water, cooled in turn by the main circulating water. In addition to these main motors, BTH will supply over 900 auxiliary motors for the station with an aggregate power of about 22,000 h.p. The gas inlet and outlet temperatures are 320 and 662°F respectively.

Steam is raised in the heat exchangers at two pressures—306 and 62 lb/in^{2}g. Both the h.p. and l.p. steam are superheated to 612°F. Totally enclosed, glandless, forced circulation pumps are fitted in each feed circuit. The steam and feed conditions were chosen to give the optimum performance of the plant as a whole. The steam mains are carried in two circumferential ducts each serving four boilers and then taken on pipe bridges to the turbine hall, which is located at some distance from the reactors with its axis parallel to the line joining the reactor buildings. Here are installed four Metropolitan-Vickers 85MW turboalternator sets. The turbines are virtually standard three cylinder machines with the h.p. cylinder omitted and the i.p. cylinder modified for the dual supply of steam. The blading is of the impulse type. Deaeration of feed water is done in the condensers, the tube arrangement of which is designed to reduce the oxygen content to a minimum. Two stages of feed heating are used and the system includes ejector heaters and gland heaters. Separate dump condensers are included for start-up and shutdown conditions. A unit consists of one reactor and two turboalternator sets. These will normally work independently but if necessary the two units can be cross-connected. The station will have three main electrical systems: 6·6kV, supplying all motors over 150 h.p. and the auxiliary transformers; 415V from the auxiliary slip-down transformers; 240V d.c. battery supply in three sections—no 1 reactor, no 2 reactor, turbine hall. Hydrogen cooling will be adopted for the alternators which will generate at 11·8kV, the output being stepped up in four 11/132kV BTH transformers for the grid supply. Circulating water

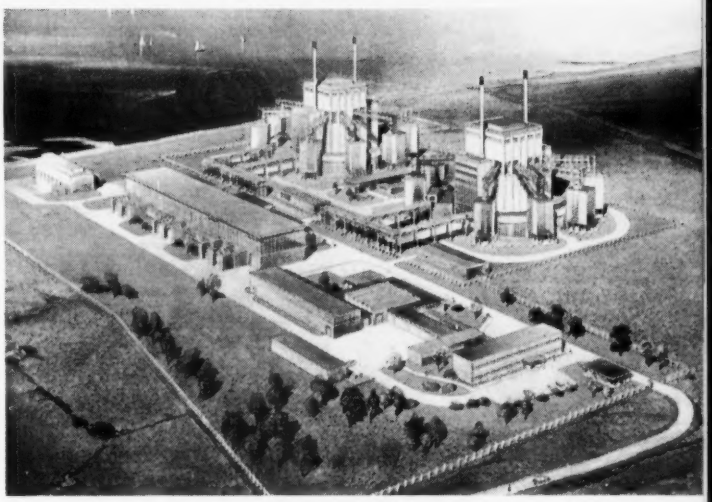
for the condensers will come from the River Severn. It will be taken through guard screens and intake tunnels to the main pump house near the shore. The pumps discharge to separate culverts for each turbine set and after passing through the condensers the water is returned to the river through four outfall culverts.

The site is divided into two distinct areas separated by a fence—'active' and 'non-active.' The first includes the strictly nuclear part of the station and the second the conventional part such as the turbine hall, administrative block and workshops. Access to the active area is through a control gate but a special gate is also provided through which new fuel can be delivered to the fuel store without the lorry having to enter the 'active' area.

Control of the entire station will be carried out from a single centre, most of the equipment for which will be supplied by BTH and Sunvic, AEI companies. Reactivity control will be by rod as at Calder Hall, at least 150 actuator units being supplied by BTH.

Of particular interest is the burst slug detection gear which is to be provided by Sunvic in cooperation with Dowty Nucleonics. Basically, this is similar to the Calder system. In other words, groups of four channels will be monitored every half-hour, any fission products in the sample being precipitated onto a wire which is then passed in front of a scintillation counter. The system differs in the method of handling the vast amount of data coming from a total of 6,000 channels—i.e. about 290,000 'bits' per day. At Calder separate miniature chart records are kept but this was considered not only impracticable but undesirable since the operators are really only interested in abnormalities. Consequently, at Berkeley, digital computors with magnetic drum memory stores will be used. During each sampling, the count will be passed through a scaler, converted to a binary number, and stored in a drum. When an abnormal count is registered, alarms are given and the offending channel can be speedily located. If required, the history of this particular channel during the last 24 hours can be extracted from the store and the counts printed out on an electric typewriter. There will be 17 precipitators for each reactor with 10 more for bulk sampling and spares. Each reactor will have two computors and there will also be a spare one. The system has the maximum flexibility and the sampling period can be varied at will. For example, one computer could sample a complete reactor at half the speed. Starting of individual plant items will be done locally on phone instructions from the central control room but, once running, control will pass to the centre. Main features of the reactor supervisory instrumentation are:

1. Continuous indication and recording of neutron flux
2. Continuous indication of: selected fuel element temperatures, bulk gas temperatures and control rod positions
3. Print-out of channel activity from burst slug system.



Most distinctive feature of the AEI-JT design is the radial layout of the heat exchangers round the reactors. This model does not represent actual Berkeley site

4. Comprehensive visual and audible alarm system warning of onset of non-urgent fault condition
5. Automatic reactor shut-down system indicated by urgent fault conditions

On start up, the blowers are first started at a low speed and the control rods are slowly withdrawn, the plant temperatures being allowed to rise at a controlled rate. As the temperatures rise the blower speed is increased until steam of the right conditions is being generated, when the turbines are started. When on the bars, the sets will be freqeuncy-controlled, the load being changed by speeder gear adjustment. The reactor gas outlet temperature will be kept constant by automatic control of the rods. Load changing is thus by blower speed and turbine speeder gear control only. Automatic control of the latter from the h.p. steam pressure, would permit single switch load control of the whole plant.

The members of the AEI-John Thompson Nuclear Energy Co Ltd and their part in the Berkeley project are:

THE BRITISH THOMSON HOUSTON CO LTD:	*gas blowers, motors, and control gear; grid and station transformers; control rod actuators; station control equipment*
METROPOLITAN VICKERS ELECTRICAL CO LTD:	*turboalternators, special instrumentation*
SUNVIC CONTROLS LTD:	*reactor instrumentation and burst cartridge detection gear*
JOHN THOMPSON LTD:	*reactor pressure vessel, thermal shielding, heat exchangers*
SIEMENS BROS LTD:	*cables*
FERGUSON PAILIN LTD:	*switchgear*
HOTPOINT ELECTRIC APPLIANCE CO LTD:	*refrigeration equipment*

associated with the group are:

BALFOUR, BEATTY & CO LTD:	*civil engineering*
JOHN LAING & SON LTD:	*civil engineering*
ISOTOPE DEVELOPMENTS LTD:	*special instrumentation*

The civil consultants to the Company are W. S. Atkins and Partners; the quantity surveyors, Messrs Gardner & Theobald

The Managing Director of the AEI-JT Nuclear Energy Co Ltd is Mr Harry West; and the Chief Engineer, Mr S. A. Ghalib

Using only six heat exchangers for each reactor results in a compact, economical arrangement of buildings. From the estuary, pipes bring circulating water for the condensers

SPHERICAL SHELL CHOSEN FOR BRADWELL

THE BRADWELL-ON-SEA station to be built by the Nuclear Power Plant Co Ltd will cover about 142 acres of a site on the south shore of the River Blackwater. It is proposed to install generating capacity aggregating 390MW but this includes a margin for subsequent improvement in reactor performance; the initial guaranteed net sent out output will be 300MW. There will be two reactors, each in a spherical pressure shell 67ft dia. and 3in. thick. These are housed in separate reactor buildings which are however joined at their lowest level. The graphite core is supported on a grid, generally similar to that used at Calder Hall, which transfers the weight through the shell to a series of pivoted support legs ranged in a circle. The fuel charging is from the top and will be done on load. For this purpose, on the charging floor there is a travelling gantry on which a traversing charge machine can cover the whole area.

The core is centrally disposed in the pressure shell and the graphite block is about 45ft dia. and 31ft high. It contains about 2 600 vertical fuel channels. It will be recalled that the NPPCo in association with the Great Lakes Carbon Co of New York recently formed a joint company—Anglo Great Lakes Corporation—to manufacture reactor-grade graphite in a new factory on Tyneside. The fuel elements are natural uranium rods just over 1in. dia. sheathed in magnesium alloy. The biological shield will be about 8ft thick. From the drawings, the thermal shield coolant outlets appear to be rather low.

There are six heat exchangers to each reactor and they are closely grouped in threes on each side of the reactor buildings inside glazed enclosures. The CO_2 pressure is 130 lb/in^2 and the gas is handled through 5ft dia. ducts. These enter and leave the pressure shell normally and separation between the hot and cool gas is effected by a pair of annular dished baffles which seal the upper face of the core from the lower. The heat exchangers are dimensionally similar to those used at Calder Hall but for double the unit heat output. This would give a total output per reactor of about three times the Calder output, or say 540MW heat. Axial flow blowers, set radially with regard to the reactor below the heat exchangers, circulate the coolant. These are driven by standard a.c. induction motors supplied from the auxiliary turboalternators. Control is effected by

varying the speed of these sets. Each duct circuit lies in one plane, thus simplifying support and expansion problems.

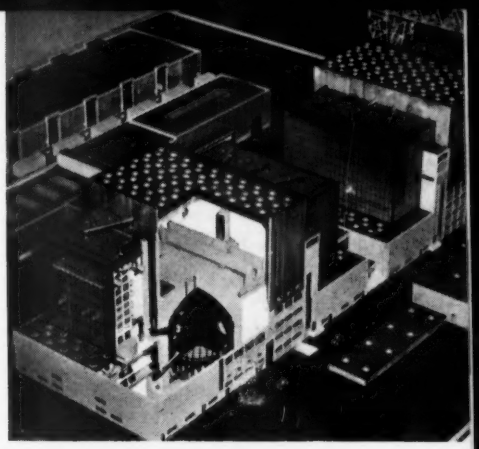
The turbine hall is situated alongside the reactor buildings and houses the six 55MW main turboalternators. These are dual-pressure machines (730 lb/in²g: 700°F, 180 lb/in²g: 700°F) with twin exhausts. Two boilers are grouped to supply one set through a common receiver with interconnection of one set capacity between each of the six steam receivers. Running at the normal speed of 3 000 rev/min, the turbines will drive standard hydrogen-cooled alternators generating at 11·8kV. The output will be stepped up to 132kV and switched at that voltage. Two station transformers and six unit transformers will be provided. The three 20MW auxiliary turboalternators, one of which is a standby unit, are housed in a low building alongside the main turbine hall and adjacent to the main control room. From here, the operation of the entire station will be kept under automatic control.

Circulating water will be taken from the river side of a baffle wall built out in the estuary. Recirculation will be prevented by returning the warmed water on the land side of the baffle.

It is anticipated that fuel changing of a few channels will take place almost every day and irradiated fuel elements will be stored in a cooling pond on the site before removal to a UKAEA processing plant.

In addition to normal power station facilities such as workshops, stores, canteens etc Bradwell will have additional services such as decontamination service, fuel store, change rooms, laundries, effluent treatment plant, health physics laboratories and solid active waste disposal areas.

In erecting the plant, the contractors propose to use a giant portal-type crane known as a goliath. With a capacity of 200 tons it will have a height of 170 ft and a clear span of 167 ft.

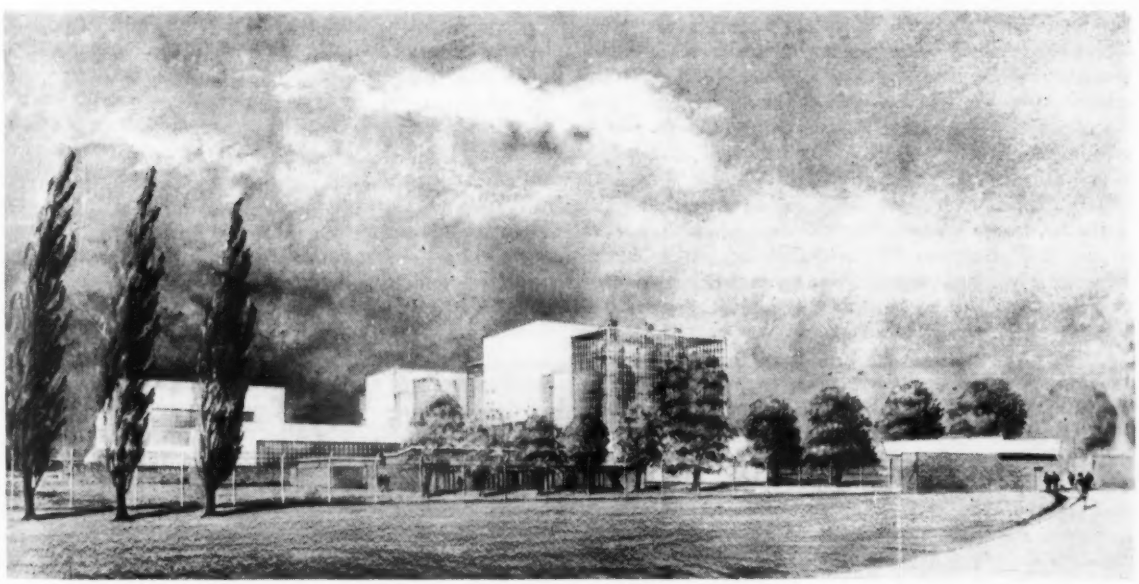


Gas ducts to the spherical shell are symmetrically disposed. Inside, baffles separate the hot gas from the cool. Over far reactor is Goliath 200 ton crane used for building the plant

The members of the Nuclear Power Plant Co Ltd and their share in the Bradwell contract are:

C. A. PARSONS & CO LTD:	*turboalternators, condensers, feed heaters, gas blowers, ductwork, instrumentation, transformers*
A. REYROLLE & CO LTD:	*switchgear, control gear*
HEAD, WRIGHTSON & CO LTD:	*heat exchangers (with Clarke, Chapman), graphite installation, shield cooling, blowdown and evacuation systems*
SIR ROBERT MCALPINE & SONS LTD:	*civil engineering, buildings*
WHESSOE LTD:	*reactor pressure vessels*
STRACHAN & HENSHAW LTD:	*fuel handling equipment*
ALEX. FINDLAY & CO LTD:	*structural steelwork*
CLARKE, CHAPMAN & CO LTD:	*heat exchangers (with Head Wrightson)*
PAROLLE ELECTRICAL PLANT CO LTD:	*coordinating division of the NPPCo*

The Chairman of the Nuclear Power Plant Co Ltd is Sir Claude D. Gibb, and the Technical Director Dr A. T. Bowden. The architect of the station is Maurice Bebb.



Three-inch plate for the pressure vessels at once permits the Calder system to be scaled up. A well-known reactor engineer discusses . . .

HOW THE STATIONS COMPARE

ALTHOUGH THE NEW DESIGNS all use the basic system of the Calder Hall station they represent very considerable advances. Not only are they bigger: they are also better. In other words, the improvement in output is due mainly to a simple increase in size but also in no small measure to higher thermodynamic efficiency. The greatest difference from Calder Hall arises from the changed operational requirements. Calder was designed primarily to produce plutonium: the new stations are for base-load electricity generation and are designed to run continuously for about 80 per cent of their life.

On the question of sheer size of reactor, it should be remembered that in Calder Hall, the designers set out to devise the smallest natural uranium reactor that would work. As it happened, this turned out to be the biggest pile that could be got into the largest pressure vessel the makers were prepared to build at that time. It was then thought that 2-in. plate was the thickest that could be welded on site to the Class I standards required. Now, with Calder operating, all the groups are prepared to weld 3in. plate and this has automatically meant an increase in output due to size alone. For a cylindrical vessel, a 50 per cent increase in thickness permits a 50 per cent increase in the product *pressure* × *diameter* for the same hoop stress. Suppose, for example, that this is invested in 22·5 per cent more pressure and 22·5 per cent more diameter. The first effect of the larger size is that a bigger core can be accommodated and so the number of channels can be increased—in fact 50 per cent more. Secondly, the increased core diameter will bring the size well over critical, thus allowing the centre zones to be charged with some neutron-absorbing material or possibly with depleted uranium. This has the effect of flattening the flux distribution and increasing the ratio of mean to maximum flux. In turn, this leads to an evening out of the heat rating among the channels from the centre to the periphery so that the average value is increased. Such a flattened reactor could be expected to have an output of about 1·4 times the unflattened one.

On size alone, therefore, this simple scaling would be expected at least to double the output (1.5 × 1.4). If, in addition, the gas pressure is put up, the increased coolant density will improve the heat transfer rates for the same mass flow. It might therefore be assumed that due simply to increased pressure vessel thickness an improvement of reactor heat output of about three times on the Calder Hall figure is possible.

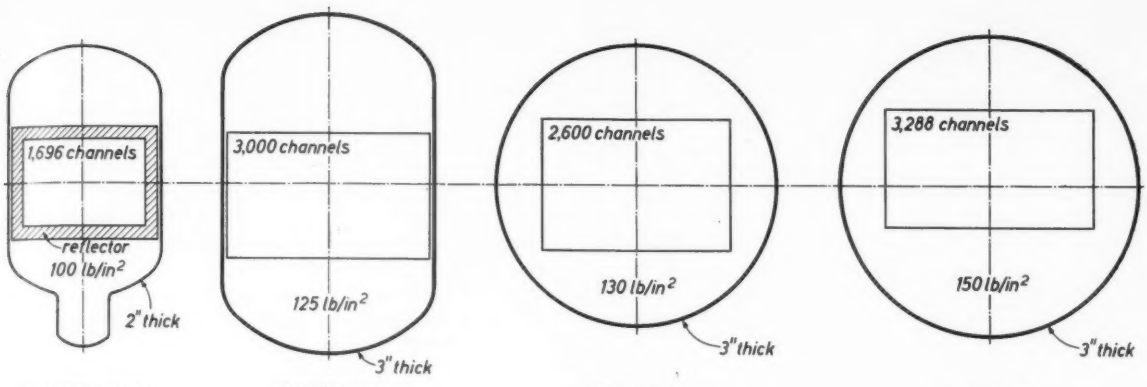
Very approximately, this is in fact what the AEI-JT design does. The pressure vessel is similar to the Calder shell but the hoop stress has been raised by about 14 per cent, thus permitting a 25 per cent increase in gas pressure combined with 37 per cent greater diameter.

When a spherical reactor vessel is chosen—as it has been by both the NPPC and GEC-SC groups—the thin shell stress formula ($f = pd/4t$) shows that the diameter may be twice that of a cylindrical shell for the same stress. This means that an even larger core can be accommodated. Some, but not full, advantage of this fact has been taken by both of these designs.

A striking unanimity of thought is apparent in the core lattice dimensions. Taking the published figures of core diameter and number of channels and allowing 3ft of reflector all round (Calder Hall has 2½ft) the pitch of the channels comes to about 8⅛in. in all three designs. This is only slightly more than the Calder pitch (8in.) and indicates the lack of room for manoeuvre in this direction with this type of reactor.

Fuel loading must have been one of the most difficult tasks in the whole project, for a requirement is that fuel charging of a few channels will probably take place daily. The Berkeley and Bradwell designs play fairly safe and follow the Calder principle of charging and discharging through the same hole on top of the reactor vessel. For the Scottish station however, the GEC-SC group have made a radical change and the reactor is loaded and unloaded through charge tubes in the base of the reactor vessel. This has two obvious operational advantages: the top of the core is left free for the gas sampling tubes and the control rods; the rather complicated cable hoist and automatic grab mechanism for lowering and hoisting the fuel elements is eliminated. What problems are introduced instead remain to be seen.

The gas temperatures used by two of the groups show considerable variance (the NPPC have so far not disclosed any). The gas outlet value at Calder is 637°F; at Berkeley it will be 662°F while the GEC have taken it up to 745°F. Since the NPPC's steam temperature is the same as that of the GEC, their gas temperature also is likely to be about 750°F. The only can temperature available is the GEC's—797°F—and it is understood that the firm's metallurgical research work has shown that the *Magnox* used for canning is satisfactory up to nearly 900°F. AEI show a more cautious approach to the problem and, although the can temperature has not been disclosed, from the bulk gas temperature it is unlikely to be



Although more difficult to fabricate, spherical pressure vessels are chosen by two groups. Calder Hall on the same scale for comparison

so high as the GEC figure. In this connexion it is interesting to note that at Calder, the difference between the bulk gas outlet and the maximum can temperature is 130°F; the GEC have narrowed this to only 72°F. This is probably due to the flux flattening process mentioned earlier and it is likely that the other designs show the same tendency.

Although the channel spacing is probably much the same in each reactor, the proportions of height to diameter, and number of channels show some variations. Taking the ratios of diameter to height and allowing 3ft reflectors all round, the relative ratios as GEC—1·95, NPCC—1·56, AEI-JT—1·6. It is seen, therefore, that the GEC design differs markedly in having a relatively short channel with a correspondingly greater number. This possibly will give a low value to the blowing power required.

For the gas arrangements, there is no unanimity although there is general acceptance of 5ft ducts. Firstly, on the number of boilers the NPPC are making do with six per reactor instead of the others' eight—despite the fact that the installed capacity at 390MW is greater than the others. These exchangers are said to be the same size as the Calder ones but with double the heat duty; it must be assumed that a very advanced form of heat exchanger surface is used. Since the boilers are a large item of cost, any move to reduce their number is a step in the right direction. The inlet and outlet to the reactor shell is similar to Calder in the case of the AEI-JT Berkeley reactor; the others, being spheres, are quite different. It is obviously necessary to separate the hot from the cooled gas and while this can be done relatively simply in a cylindrical shell, it is not so straightforward when it comes to a sphere. The GEC have adopted the principle of an inner shell of 'relatively thin steel plate.' The gas inlets enter the main shell on the horizontal diametral plane and the gas then passes down through the grid by a fairly tortuous path and up through the coolant channels inside the inner shell. The outlets pass through the inner and outer shells. As well as separating the hot and cool gas, the inner shell is intended to provide a measure of thermal shielding and so protect the actual pressure shell from radiation. Just how effective this will be, is not easy to see. There will undoubtedly be some heat leak through the inner shell and while this could be minimized by lagging, its maintenance and eventual replacement would seem to be difficult to say the least. In addition, the gas outlet ducts and the channel service tubes have to pass right through both shells. One can imagine difficulties in differential expansions between the two shells. Possibly the pipes are not actually attached to the inner shell but are simply a loose fit. In this case, some bypassing of gas must be allowed for. With a similar problem, the NPPC have adopted what seems to be a very straightforward solution. True, there are extensive baffles inside the shell, but there are two of them at some distance apart and the amount of heat fed back is not likely to be large. They therefore do not need insulation and so should require no maintenance.

For gas blowing, two of the groups use conventional axial flow blowers while the GEC have decided to install centrifugal blowers actually inside the heat exchanger vessels. Methods of driving the blowers vary. Most distinctive, the NPPC are to install auxiliary turboalternators entirely for station supplies so that the main sets supply only the Grid. As base load stations, it is not anticipated that there would be much need for a great range of speed variation in the gas pumping speed. Both Bradwell and Berkeley will drive their blowers by a.c. induction motor but, whereas the former will obtain speed variation by altering the speed of the auxiliary sets, the latter will use hydraulic couplings. For the sort of range required, one would have thought that the AEI-JT method was probably the simplest.

In the choice of steam conditions, the NPPC have gone to the limit with the gas temperatures available. The GEC have adopted the same initial temperature (700°F) but a substantially lower pressure 590 lb/in²a against 745. The AEI-JT design, compared with these, has a comparatively moderate steam pressure at 320 lb/in² a with however 612°F as the temperature. In both the GEC and AEI-JT designs, the temperature approach at the top end is about 50°F—which incidentally is just about the Calder figure. AEI's reasons for selecting these conditions are not clear and at first sight it would appear that the mass flow per kW is rather high. This design is also at variance

with the others in using only four sets against the other groups' six. This could be due to the fact that the Metrovick turbines to be used at Berkeley are probably basically standard 100MW machines, of the type being installed at Castle Donington coal-fired station, with the h.p. end omitted.

All the designs use the dual-pressure cycle, with the l.p. steam admitted into the h.p. casing at a selected point. Unlike Calder Hall, the l.p. steam is given a very high degree of superheat—right back to the h.p. figure in the NPPC and AEI-JT designs, in fact—and the effect on the cycle is equivalent to an interstage reheat, the fresh hot steam mixing with the h.p. steam and raising its temperature at constant pressure.

All these designs have adopted regenerative feed heating. It will be recalled that this was rejected at Calder Hall (although it was a feature of the Pippa design study) because it was desired to keep the coolant temperature at entry to the reactor as low as possible. This no longer obtains, and with feed heating and better initial steam conditions the thermodynamic efficiencies are probably approaching 30 per cent. In all cases the turbines seem to be at some distance from the boilers and there is bound to be some loss in the mains in addition to expansion difficulties. This is particularly true of the Berkeley station and unless there are special site considerations which positively dictated this layout, some more compact arrangement might have been thought preferable.

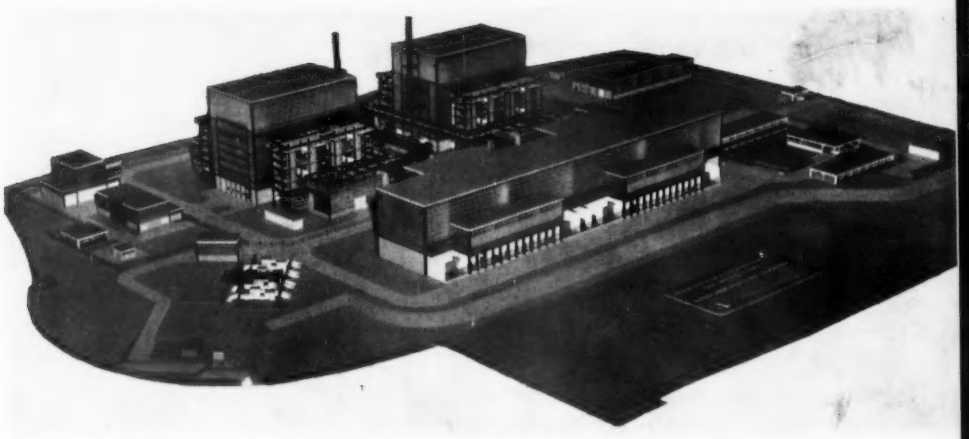
Little has so far been announced about the instrumentation, but the news that the Berkeley station is to use computers in conjunction with the gas-sampling system is interesting. These new stations have something like twice the number of channels in the Calder Hall reactors and a straightforward extension of the multiple chart recording system seems both unnecessary and even unsatisfactory. With the Sunvic system the operators will be able to concentrate on abnormalities in readings and the system should also be more accurate.

Summing up, the new stations have perhaps more in common with the original Pippa (Moore and Goodlet BNEC Symposium) than with Calder Hall as actually built. The single factor of 3in. steel has led to an increase in size and pressure but the thermodynamics of the heat exchanger and turbine have also been improved. Further improvements can be expected from even thicker pressure vessels: failing this, new types of canning material—possible beryllium—will have to be considered. The designs all show individual features of interest and when the second round of stations is announced it will be interesting to see what interchange of ideas has taken place in the interim. So far, no information has been released on proposals for maintenance. These stations must have a life of at least 20 years to pay off the enormous cost. It is inconceivable that in that period nothing will ever go wrong and it would be interesting to know how the firms propose to deal with such eventualities.

Leading details of the new British power stations.

STATION	CALDER HALL	SCOTLAND	BRADWELL	BERKELEY
Authority	UKAEA	SSEB	CEA	CEA
Main Contractor	several	GEC Simon-Carves	Nuclear Power Plant Co	AEI-JT
Reactors x heat output MW	2 x 180	2 x 625	2 x 540 (?)	2 x
Turbines and rated output MW	4 x 21	6 x 60	6 x 55 plus 3 x 20 auxs.	4 x 85
Min. sent out output MW	ca.70	320	300+	275+
Graphite dia x height ft	36 x 27	50·5 x 28	45 x 31	48 x 30
Core dia x height ft	31 x 21	44·5 x 23	39 x 25*	42 x 24*
No. of channels	1696	3288	ca. 2600	ca. 3000
Channels/ft²	2·25	2·18	2·16	2·16
Lattice pitch in.	8	8·25	8·16	8·16
Presure vessel dia ft	37	70 (sphere)	67 (sphere)	50
Pressure vessel height ft	70	—	—	80
Pressure vessel thickness in.	2	3	3	3
Static gas pressure lb/in.	100	150	130	125
Stress lb/in. (pd/4t or pd/2t)	11 000	10 500	8 700	12 500
Blower power MW per reactor	5·44	12·6		8 x 2·24
Gas mass flow lb/h	$7·2 \times 10^6$	$20·3 \times 10^6$		$22·3 \times 10^6$
Gas inlet temp °F	284	392		320
Gas outlet temp °F	637	745		662
Can temperature °F	767	797		
No. of heat exchangers per reactor	4	8 (19·5 ft x 7·35 ft)	6 (18 ft x 80 ft)	8 (17·5 ft x 70 ft)
Steam conditions, h.p. lb/in.² (a): °F	200 : 590	590 : 700	745 : 700	320 : 612
Steam conditions, l.p. lb/in.² (a): °F	53 : 340	160 : 670	195 : 700	77 : 612
Condenser vacuum in. Hg	28·25	28·9	28·9	29
Steam mass flow h.p. lb/h	396 000 (77%)	43 100 000 (67·2%)		1 120 000 (68·3%)
Steam mass flow l.p. lb/h	118 600 (23%)	69 500 000 (32·8%)		520 000 (31·7%)
Total uranium tonnes	2 x 130	2 x 251		
Total graphite tonnes	2 x 1200	2 x 2150		

* assuming 3′ reflector



Left out of the first round of CEA power stations, the English Electric, Babcock and Wilcox, Taylor Woodrow design is at present being considered for the third station—at Hankley Point, Somerset. The Authority say that they intend to proceed with construction as soon as planning approval and the consent of the Minister of Power is obtained. Its capacity will be about 275MW (s.o.). The architect to the group is Frederick Gibberd

IS APPEARANCE IMPORTANT?

an architect gives his views

THE ARCHITECTURAL and social problem posed by the development of atomic power is to ensure that it does not bring with it the chaos that accompanied the rise of mechanical power in the first industrial revolution. Visual harmony is as essential to man's spiritual welfare as atomic power is to his physical welfare.

It is encouraging that in these projects, architects have been members of the team from the start. In engineering projects they are usually ignored altogether or merely brought in to apply a last minute 'face lift.' This is a legacy from the nineteenth century when architects were not interested in industry and preferred buildings that allowed them to indulge their fancy for historical trimmings. They concentrated on the banks and town halls and public buildings, leaving the new exciting problems of warehouses, factories and dockyards to engineers. The collaboration of scientists, technicians, architects and builders is of great importance and is growing closer all the time.

The task of the engineer is precise; to create orderly economical arrangements giving maximum efficiency. The task of the architect is to render these arrangements visually meaningful. Using the language of materials and techniques, he creates images which excite and move the imagination. This applies to a cathedral, a house or a power station.

The dynamic and exacting requirements of modern technology have often led the engineer to succeed where the architect has failed. On the one hand, we see the gleaming aluminium shells of an oil installation and on the other, the pomposity of the typical brick power station. In industrial architecture, the architect must be prepared to throw away his pet conceptions of scale, proportion, mass, monumentality, etc. His demand for architectural order must not lead him to disguise the essential nature of the processes, but rather to exploit them.

The formal problem of a nuclear power station is basically that of a large central mass (the core and its surrounding shell) with the smaller masses of the heat exchangers disposed symmetrically about it. These are related to a conventional turbine house and ancillary laboratories, workshops and welfare buildings. Intrinsically the reactor group is dominant and sets the key for the whole scheme.

Visually, with the exception of the as yet unaccepted English Electric, Babcock & Wilcox, Taylor Woodrow design, these projects are disappointing. The GEC station for Scotland reveals little of the processes involved and its enclosure is inexpressive. The Berkeley design by the AEI-JT group is much better: the processes are clearly articulated, though the result is still massive and monumental. It is a pity that the ancillary buildings are not more coherent and simple in contrast to the inevitable intricacy of the main buildings. The EE-BW-TW concept is the most satisfactory, and has nicely articulated exposed plant elements in contrast to clean blocks clad largely with glass. This meets the challenge of industrial architecture and produces a visual order and coherence which is worthy of the technological achievement it expresses. The Nuclear Power Plant Co's Bradwell project attempts monumentality and succeeds in looking like so many factories and power stations—afraid to let go of architectural values which are meaningless in this age.

David Allford

In industrial irradiation facilities, stringent precautions are necessary for personal safety

Personnel protection instruments for use in g

by E. W. Pulsford, AERE, Harwell
and C. C. H. Washtell, Labgear (Cambridge) Ltd

LE NOMBRE TOUJOURS CROISSANT de sources de radiation gamma à haute intensité disponibles engendre des problèmes de protection de santé. On décrit une chambre typique pour l'irradiation, comprenant un enclenchement de sécurité ingénieux. Il existe néanmoins une possibilité (bien peu probable), qu'un grain de cobalt peuve rester dans la chambre ? on décrit un dispositif d'alarme sensible à la radiation gamma de haut niveau, qui donne une garantie de sécurité supplémentaire. Si cet éventualité surgissait, il serait peut-être nécessaire que les membres du personnel entrassent dans la chambre ; on décrit un type nouveau de moniteur-dosimètre portatif.

DIE STETS WACHSENDEN Mengen verfügbarer Gammastrahler hoher Intensität rufen Gesundheitsschutzprobleme hervor. Eine typische Bestrahlungszelle mit sinnvollen Sperrvorrichtungen wird beschrieben. Es besteht jedoch immer eine (kaum wahrscheinliche) Möglichkeit, dass ein Kobaltkügelchen in der Zelle zurückbleibt ; eine an Hochniveau-Gammastrahlung ansprechende Alarmvorrichtung, welche in einem derartigen Fall einen zusätzlichen Schutz gewährt, wird beschrieben. Sollte dieser Fall zustande kommen, dann würde es vielleicht nötig sein, dass das Personal die Zelle betrete ; ein tragbarer Dosisrate-Monitor wird beschrieben.

LA CRECIENTE DISPONIBILIDAD de fuentes de rayos gamma de gran intensidad está creando problemas sanitarios. Se describe una célula típica de irradiación que engloba ingeniosas interconexiones de seguridad. Sin embargo, existe todavía la remota posibilidad de que se deje en la célula un grano de cobalto, y se reseña un grupo de alarma de rayos gamma de alto nivel que proporciona una salvaguarda adicional. Si ocurriera este caso, es posible que fuera precisa la entrada de personal en la célula, y es descrito un nuevo tipo de monitor portátil de dosis.

ВОЗРАСТАЮЩАЯ ДОСТУПНОСТЬ источников гамма-излучения вызывает проблемы охраны здоровья. Описывается типическая камера для облучения, включающая остроумные предохранительные блокировки. Несмотря на это существует маловероятная возможность, что кобальтовый шарик останется в камере; в связи с этим описывается обеспечивающее дополнительную безопасность сигнальное устройство, действующее под влиянием гамма-излучения на высоком уровне. В этом случае может оказаться нужным, чтобы обслуживающие вошли в камеру; описывается портативный монитор мощности дозы нового типа.

WITHIN the last few years, consequent upon the availability of the gamma-active isotope of cobalt (^{60}Co) in considerable quantities, a new field of investigation has been opened, particularly interesting to chemists and biologists, for the study of chemical changes which take place in matter when it is subjected to large-scale gamma irradiation. Although work on the uses of such penetrating radiations has hitherto mainly been confined to the Technological Irradiation Group of UKAEA and some of the larger chemical laboratories, enough evidence has been accumulated to indicate that a new and valuable tool is now available to Industry.

The use of high-level radiation sources poses some special problems because of the health hazards involved. Irradiation techniques are therefore normally carried out in a special chamber, incorporating massive shielding built in the form of a labyrinth, which offers the maximum degree of protection to those engaged in operating the unit. For purposes of control, an ionization-chamber monitoring instrument suitable for remotely indicating the radiation intensity within such a chamber, has already been described (NUCLEAR POWER *May 1956*), but there is an important requirement for instruments which will give unmistakable warning and, additionally, provide some indication of the hazard, should dangerous conditions be present when it is necessary to enter the irradiation cell. It is with these latter aspects that the present article is concerned.

The irradiation cell and interlock

A typical cell in which irradiations are performed consists of a small room (about a 6 foot cube) surrounded by very thick walls and a roof of concrete. Access to this room (Fig 1) is by way of a side corridor whose entrance is furnished with a steel grille door. The radioactive source is attached to a long flexible rod operating through a serpentine tube, as shown. The source may be either pushed into the

gamma irradiation cells

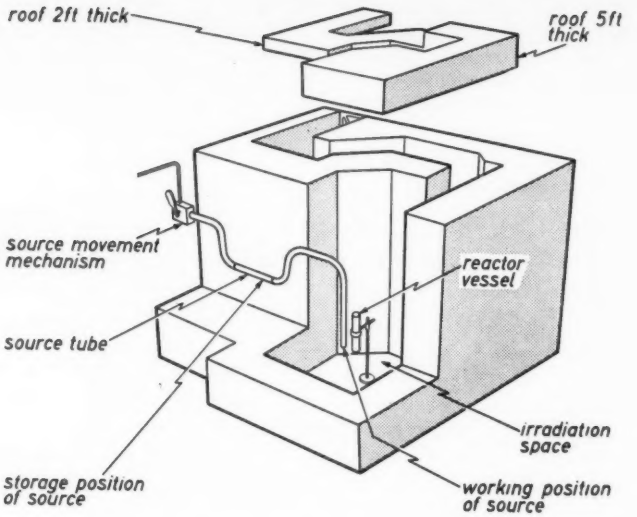


Fig 1 For high-intensity gamma irradiations, small cells in massive concrete with a labyrinth entry are used. This one is typical of those used at the AERE

'working' position or withdrawn into the 'safe' position, where it is retained by a stop in the mechanism.

Movement of the source is governed by a mechanical interlock mechanism so arranged that the access door must be closed and locked before the source can be moved from the safe to the working position. Conversely, the source must be retracted to the safe position before the access door can be unlocked. The 'captive-key' system is employed. There is a key which is common both to the door and the interlock mechanism. This key cannot be withdrawn from the door until it is safely locked. On using it to unlock the source-moving mechanism, it remains captive until the source is again made safe.

In this way a considerable factor of safety from the accidental irradiation of anyone entering the cell is obtained.

Need for further safeguard

But there is a source of danger—albeit rather remote—because of the mode of construction of the cobalt source itself, which may consist of a short cylindrical steel holder containing a number of pellets of cobalt 60 retained by a lid secured by a bayonet catch. It is felt, for instance, that during movement of the source there is a chance of this lid becoming detached and allowing one or more of the cobalt pellets to fall out to the floor of the cell. Should this occur unawares there would arise the danger of severe irradiation of any worker entering the cell. The high-level Gamma Alarm Unit (Fig 2) is installed to guard against the danger arising from such accidents.

The main unit of this equipment is usually wall-mounted in a convenient position outside the cell, and the small metal box containing a geiger counter and its load resistor are wall- or floor-mounted inside the cell at a place suitable to the operations to be carried out: the position is not critical. The interlock switch is a microswitch adapted to the mechanism so that it closes just as the source reaches its safe position.

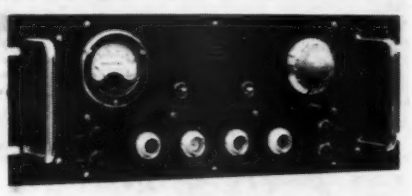


Fig 2 A gamma alarm unit is used to warn personnel should there still be a dangerous level of activity in the cell after the source has been removed

The gamma ray detector

Because the gamma ray field to be detected is intense, the high-current geiger counter is very suitable as a detector. This is a small halogen-quenched counter which is capable of delivering a current up to 50 microamperes, enabling it to work a sensitive moving-coil relay without recourse to any electronic amplification; consequently the alarm unit circuit is very simple in character.

The relationship between the geiger counter current and the intensity of the gamma irradiation is logarithmic when the geiger counter is used with a series resistance of 2 megohms and operated at the appropriate polarizing voltage. In terms of gamma tolerances, a typical figure for 25 microamperes of counter current is 40, based on a dose rate of 0·3R per week of 40 hours.

In order that the life of the geiger counter shall be as long as possible, arrangements are made so that it is polarized only when monitoring is actually in progress. How this is done will appear when deal-

ing with the circuits of the Alarm Unit. At other times the h.t. voltage is not switched on and the counter passes no current. It is, however, being subjected to intense gamma irradiation, but experience shows that there is little, if any, deterioration of the counter on this account. There are counters, still operating successfully, which have been installed for upwards of a year.

The circuits of the alarm unit

The relatively simple circuits are shown in Fig 3. The mains supply is transformed in T1, so that 230V and 24V r.m.s. are available. The former is used in two ways:

1. To generate the e.h.t. supply for the geiger counter.

2. To generate a power supply for operating a slave relay, RLA.

As already mentioned, the e.h.t. for the geiger counter is generated only when required. This is ensured by arranging that the a.c. waveform is only applied to the rectifying system when a switch in the interlock mechanism is closed, and this occurs only when the source is withdrawn to the safe position. SKB is a socket to which these switch leads are attached. SWA is a test push-button on the instrument panel, supplied so that the Alarm Unit may be functionally tested while the source is exposed. It should be routine practice thus to test the whole instrument occasionally and, in any case, just before withdrawing the source so that, should the Alarm Unit be faulty, other monitoring arrangements may be made to test the absence of gamma radiation after the withdrawal is completed.

R1 and Lp1 (a neon indicator) form a signal system showing that the mains are switched on. Similarly R2 Lp2 show that the interlock switch has closed correctly.

On the closure of either the interlock switch or the test button, the 230V r.m.s. waveform is applied to the voltage-doubler system C1C2. MR1 MR2 which generates a steady d.c. voltage across C2 of $230 \times 2\sqrt{2}$ volts. This voltage (650) is rather too great for the geiger counter, which (according to specimen) has an operating voltage of about 470 volts, and so the variable potential divider consisting of R3. RV1 R4 is used and set to obtain the correct operating voltage. This adjustment is made at the factory before the instrument is sent away but may be carried out at any time with the aid of an external high-resistance voltmeter.

Between the geiger counter e.h.t. point and the earth line is a series circuit consisting of a panel meter, M1, having a full scale deflection of 50 microamperes, a sensitive but robust moving coil relay, RLB (contact S) and the geiger counter and its load resistor (X1, R7); the last two being at the end of a long co-axial cable passing through the concrete shield. By locating the load-resistor close to the geiger counter, the cable capacity is effectively removed from the counter, which should not be able to see any more parallel capacity than the minimum practicable.

The second use of the transformer secondary voltage is to generate the power supply for the slave relay RLA. The required d.c. is obtained by means of the half wave rectifying system MR3C3, and is kept in being all the time the Alarm Unit is switched on.
There is also a 24V secondary tapping, which is used to operate a warning bell on closure of the relay contacts A/2.

The sequence of operations may now be traced, as follows:

On closing the interlock switch or test button
1. Power is supplied to the geiger counter e.h.t. generator.

2. If the geiger counter is irradiated, it will pass current which will be shown on the panel meter M1. If this current is in excess of 25 microamperes, relay RLB will operate, S will close and operate RLA, which locks 'on' by itself closing the parallel contact A/1, and relieving S of carrying the operating current of RLA. A/2 will close, operating the warning bell; A/3 will close, operating a panel warn-

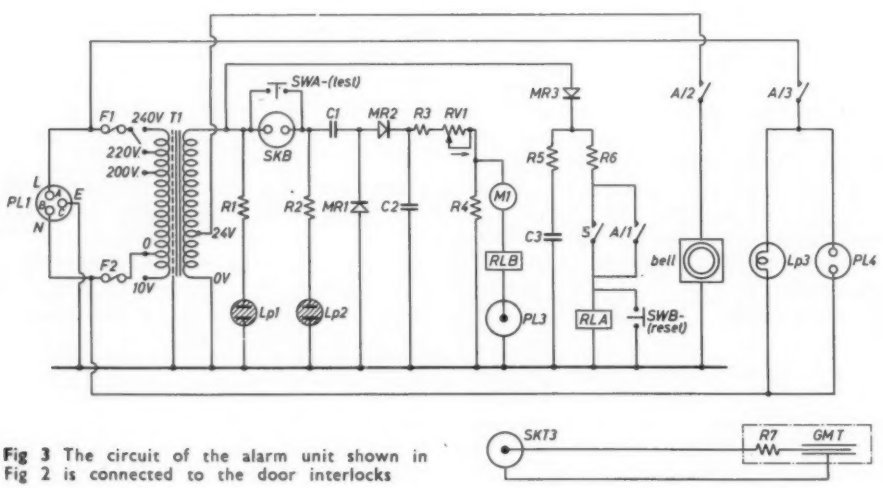


Fig 3 The circuit of the alarm unit shown in Fig 2 is connected to the door interlocks

Tolerance units	1	4	8	10		20		*	30	40		50		100
Current μ/A.	1.1	4.5	8.4	10.3	15.3	18.9	21.1	25.0	25.6	31.1	35.6	36.1	49.2	50.0
Time hrs	8	2	1											
min					30		20				10		5	

*Calibration test point GM tube type MX.119 operating at 470V Gamma source (CO^{60})

Fig 5 For the monitor of Fig 4, a typical table of tolerance units and permissible exposure times

ing-lamp and also a distant warning-lamp connected to PL4.

Because RLA is self-locking in the energized state, the warning will continue until:

a. the mains supply is turned off, or

b. the gamma field drops below that needed to pass 25 microamperes through the geiger counter, so that the reset push-button SWB may be effectively operated. This is the normal way of suppressing the alarms after a deliberate test. (Releasing the test button switches off the geiger counter e.h.t. supply).

Should there have been an accidental large spill of radioactive material within the cell, this must be investigated and cleared by remote handling methods before the Alarm Unit can be stopped from operating by the normal means. It can always be stopped, however, by switching its mains supply off if the audible warning is irritating. Because the audible warning is the most noticeable and insistent of warnings available, no cut-out switch has been fitted, so that the purpose of the Alarm Unit cannot be circumvented, so long as it is switched on.

Need for personal monitoring

In the event of personnel being required to enter the irradiation space under the above emergency conditions, the use of a portable dose-rate monitor is highly desirable. Such a unit should provide a direct reading of the gamma health-tolerance level at the operator's position of observation. It could conveniently also indicate the permissible period of time that the observer may stay at that point to receive the equivalent of one day's dose;—based on a dose-rate of 0.06 R/ per day of 8 hours.

Fig 4 shows a typical high-level gamma health-tolerance monitor suited to personnel use. It has a range

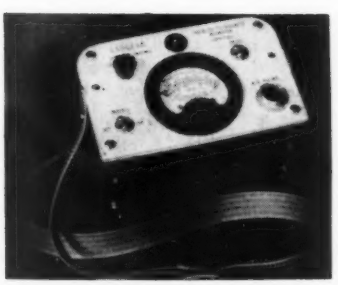


Fig 4 A gamma health tolerance meter may be used as an additional safeguard. This one has a range of 0-100 tolerance units and also a scale of permissible exposure times

of 0 to 100 health-tolerance units and uses a circuit which is directly derived from that of the Alarm Unit. Although intended for portable service, mains operation is retained in preference to the use of batteries, the restriction of the trailing mains-lead being offset by the immediate availability of the monitoring facilities in an emergency. The dose-rate indicating meter carries two scales, the upper calibrated in tolerance units and the lower in exposure times. The indicated exposure time is such that at the corresponding dose-rate level, the observer would be subjected to a similar aggregate dose if continuously exposed for one day at a level of one health-tolerance unit. Fig 5 shows a typical table of health tolerance units and permissible exposure times corresponding to g.m. tube current, taken with Cobalt 60 radiation.

Circuit

The simple circuit employed is shown in Fig 6. Neon indicator Lp1 with its series limiter-resistor indicates the closing of mains-switch SW1 which is connected via 100 m/A fuses directly to a.c. mains. Selenium rectifiers MR1, MR2, in conjunction with condenser C2, form a voltage-doubler rectifier system for the geiger-counter e.h.t. polarizing potential. Potentiometer RV1 permits the adjustment of this potential to the appropriate plateau-voltage of the counter tube.

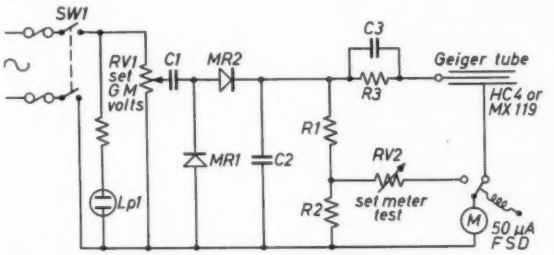


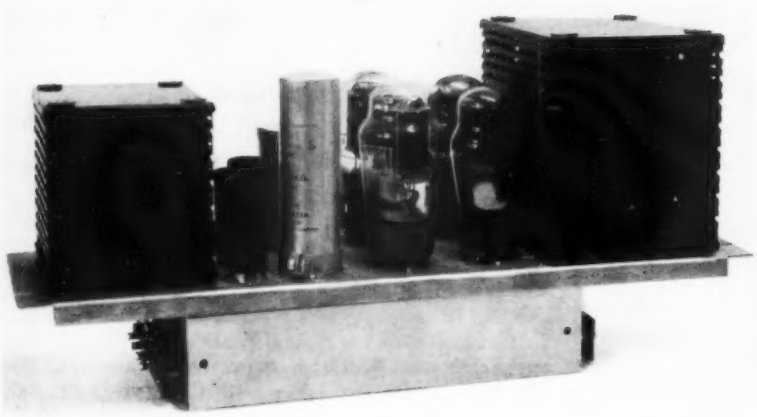
Fig 6 The circuit of the instrument of Fig 4 incorporates a calibration check circuit

To give both a measure of control over a.c. mains voltage variation and an indication of the correct operating conditions for the counter, a calibration check circuit is incorporated. High stability resistors R1, R2 across the e.h.t. supply form a potential divider whose junction may be connected, via RV2, to the counter-current indicating meter M by the operation of biased toggle-switch SW2.

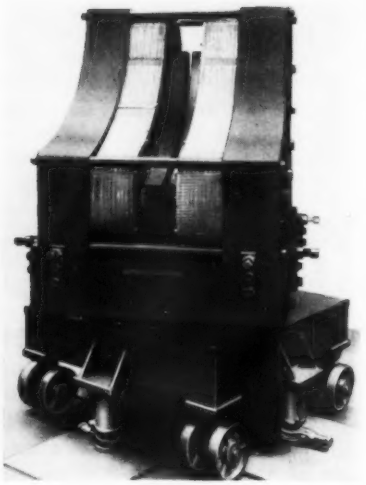
Pre-set resistor RV2 is adjusted, so that for a given counter-tube operating potential, meter M reads half-scale deflection. To test the accuracy of calibration before taking a radiation reading, it is therefore necessary only to hold switch SW2 closed and check that meter M indicates 25 microamperes, readjusting RV1 as may be required to correct any error.

In conclusion, it should be noticed that there is no current drain of any consequence in the operation of either of these monitors. Because of this, the fault-rate should be extremely low, as is obviously desirable in instruments performing the important protective function for which these are intended.

EQUIPMENT



Unit occupies minimum depth in standard panel



M-V magnet is trolley-mounted

Positive and negative stabilized supply from new Racal power unit

The Racal stabilized power supply unit type PU.156 has been designed to fill a long felt need for an efficient cheap unit which can be built in to experimental or production equipments. Its dimensions are such that it occupies the minimum depth when mounted behind a standard 19 inch front panel, thereby allowing adequate space for the circuits which it will be used to power.

It provides sufficient positive and negative HT for almost any application, and, if required, two units may be used where greater power is needed. The regulation is more than adequate for any normal requirement and the PU.156 is designed and built to a high standard to give entirely reliable service.

The unit employs a conventional series stabilizer circuit. Two 5V4G valves in parallel are arranged for full wave rectification, and the cathodes connected to two double triodes type A.1834 in parallel acting as the series valve. The single stage control circuit uses an EF.91 which obtains its reference voltage from a 150C2 neon stabilizer. As a safety precaution the anode of the EF.91 is connected to earth through 5 neons type CC3L so that the potential on the grids of the series valves remains at a fixed safe value even if the control valve fails.

The positive HT output may be varied between 200 and 300 volts by operation of the potentiometer connected to the grid of the control valve. Two metal rectifiers connected in a full wave system provide the 150V supply. The 150C stabilizer holds the voltage constant to within 0·04% for loads of 0-15 amps. An additional transformer supplies 8·5 amps at 6·3 volts a.c. unstabilized and both transformers have tappings at 10, 220, 230 and 240 volts.

Racal Engineering Ltd,
Bracknell, Berks

ElectroniK strip chart recorders used in Dido, Lido and other Harwell reactors

A considerable amount of the work done at Harwell is devoted to reactor physics, the calculation and prediction of the nuclear properties of new types of reactors. Sub-critical or just critical assemblies of different types of fuels and moderating materials are built to examine the characteristics of thermal and fast reactors. Dimple, Zephyr and Zeus are examples of these zero energy reactors which precede the construction of the power reactor itself.

Control of Zeus is achieved by movement of groups of fuel elements near the boundary of the core, the movements being adjusted according to information recorded on *ElectroniK* strip chart recorders and indicators. These instruments are used on Lido, Dido, Dimple, Zephyr and Zeus to chart continuously on linear and logarithmic scales, the neutron flux in the fission chambers and the ionization chambers of the reactors, and to record the period or doubling time of the reactor so that neutron flux may not build up too rapidly.

Honeywell-Brown, Ltd,
1 Wadsworth Road, Perivale, Middlesex

12 500-gauss magnets for AWRE

Two sets of beam-bending magnets have been built by Metropolitan-Vickers for the Atomic Weapons Research Establishment at Aldermaston.

Each set includes a large trolley-mounted electromagnet which is used to deflect the vertical beam of charged particles emerging from an electrostatic generator through 90° into the horizontal direction, where it is then directed by a smaller magnet on to one of three target areas.

Two such installations have been made on successive floors of a building. Apertures have been left in the base plates of the magnet and also in the floor so as to allow an undeflected beam to pass through to the floor below where it can then be deflected in a similar manner by the second set of magnets.

Each large magnet provides a flux density of 12,500 gauss in a 1 in. air gap between kidney-shaped pole pieces, whose surface area is approximately 150 in^2. The energizing coils are wound from hollow aluminium conductors, through which cooling water is circulated at a rate of 2 gal/min. The electrical input is of the order of 6½kW, and the weight approximately 5¼ tons.

The small magnets provide a flux density of 12,500 gauss in a 1 in. air gap between wedge-shaped pole pieces and are also water cooled. Both large and small magnets have adjustable pole pieces, which allow variation of the angles of entrance and exit of the beam relative to the boundary of the magnetic field.

Metropolitan-Vickers Electrical Co Ltd,
Trafford Park, Manchester 17

IDL double chamber beta-gauge now with remote setting

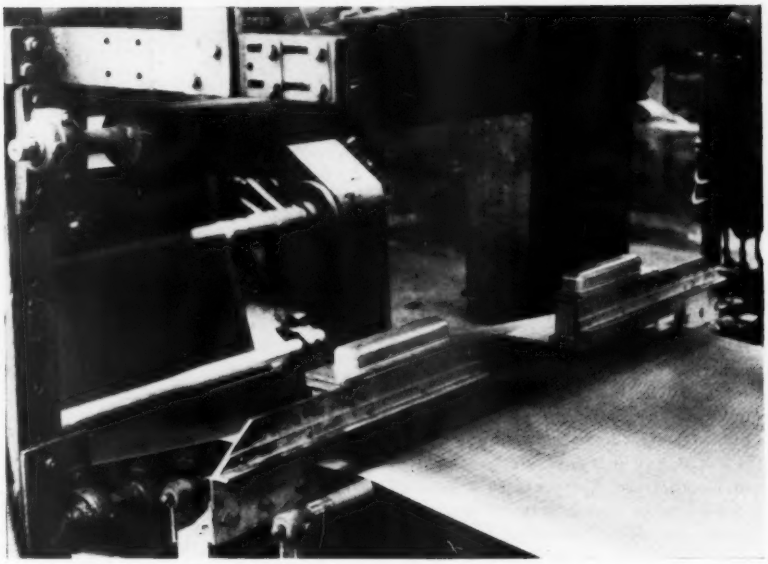
In normal thickness gauging by beta gauge, small variations from the set value are sometimes difficult to measure and systems have been used in which a null reading is obtained at the set point, variations above and below being indicated by the centre zero dial instrument. This is generally done by using a second ionization chamber and source which generate a signal of opposite polarity to that produced in the measuring chamber. Both outputs are then fed to an electronic circuit and the difference reading obtained. This has the advantage of eliminating random errors due to variations in temperature or of humidity and to source decay.

One disadvantage, formerly associated with this system, is that it was necessary to have access to the measuring unit in order to make adjustments when changing the weight of material being measured. This drawback has been overcome in the latest model of the Beta Gauge, manufactured by Isotope Developments Limited, which not only incorporates the double chamber system, but allows for weight setting at the machine operator's desk.

In order to achieve this control, the balancing chamber is fitted with a grid electrode, which has an effect similar to that of the control grid in a triode valve. The output from the balancing chamber is controlled by adjusting the voltage on the grid through a remotely sited control knob.

The Beta Gauge, type 150, produced as a result of six years' experience in the field of industrial nucleonics, is a robustly constructed and versatile piece of equipment, having the following important features:

1 The normal measuring area of 12 by 2 in. gives an average reading over a large 'sample' of the material for process control. This area can be reduced to 6 by ½ in. for investigations of local variations in the sheet.
2 The response time of the gauge is variable from 0·1 to 10 seconds, so that short-term variations can either be ignored for normal process control, or recorded during special investigations.
3 The measuring head, employing the double chamber system, is housed in a strong alloy casting, so that it will stand up to the normal rough usage encountered under factory conditions.
4 The source unit is provided with a shutter mechanism, to ensure that maintenance personnel are not exposed to undue radiation hazards.
5 Up to three measuring heads, each giving continuous readings, can be run from one gauge.
6 The 'off gauge' meter can be sited remote from the gauge, to suit customers' requirements and has a scale length of 16 in. Meter indications of plus/minus 1% are therefore easily read at a distance of 10 yards.
7 A small setting up meter is provided in the control unit, which carries the weight setting dial. This control is calibrated to suit individual customers' requirements, after the gauge is installed on the machine.
8 The sensitivity of the 'off gauge' meter to variations in weight is variable up to a maximum of plus/minus 5% for a full scale deflection.
9 The controls and components are housed in a strong cast case provided with a lock, and special attention has been given to accessibility of components for rapid servicing.
10 The power unit is housed in a separate cast case, also provided with a lock and has no controls except the main switch.
11 Recorders are available to give permanent records of gauge readings, and the output of the gauge may be used to actuate proportional controllers to govern machine speed, roll position, etc.



Typical installation of thickness gauge

Isotope Developments Ltd, Beenham Grange, Aldermaston Wharf, Nr. Reading, Berks

Built-in motors feature of new Roots-type vacuum pumps

Vacuum degassing of steels and other metals is likely to become of increasing importance in nuclear power metallurgy. Suitable vacuum pumps for degassing plant are manufactured in Germany by W. C. Heraeus GmbH, at Hanau. These pumps are of the Roots-type with two lobes per rotor. The only connexion between the rotors is external to the casing and there is no actual contact between them or with the casing. The clearances are very fine and the flow impedance is high enough to be considered a vacuum seal. To obtain the vacuum normally used in degassing (1·0 to 10mm Hg) two Roots pumps are generally used in series with a water-ring pump for backing. The pumps are made in a standard range and units are built up to suit individual requirements. For working pressures in the lower micron range, Roots pumps are available with built-in motors and no shaft seals. These are available in the range 85–3600 cu ft/min.

As an example of the pumping speed required for degassing, an average gas-content of 200 NTP litres per ton and an average pouring speed of 5 tons a minute, needs a vacuum of 3.8mm Hg to be held during pouring. This calls for a pump of 7000 cu ft/min. A lower pressure would require an increased speed.

British agents: Fleischmann (London) Ltd, 16 Northumberland Ave, London, WC2

Ceramic filters with pores of 10 microns

Until a year ago the upper pressure limit quoted for *Aerox* filters was 5,000 lb/sq in., but recent improvements in design now enable this figure to be raised by 40% to 7,000 lb/sq in. This improvement is but one indication of the constant research and development work being carried out at the company's laboratories.

Aerox filters are all fitted with ceramic elements manufactured by the company, different grades being used to suit particular applications. Pore sizes of this material range from 200 microns to 10 microns and in addition to standard material there is a special water-resistant ceramic, which may be fitted to most types of filter. The ceramic usually employed for ordinary filtration purposes is *Porsilex*, which is carefully controlled in manufacture and provides a product which may be closely matched to specific needs, providing maximum removal of solid impurities without danger of rupturing or channelling at any given pressure.

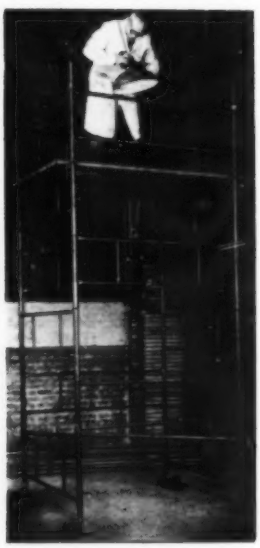
Although extremely effective in removing the bulk of moisture the elements are designed essentially to ensure complete retention of liquid as well as solid impurities, the liquids retained being easily drawn off from the system without interruption of the service, by means of a small drain cock. Cleaning of the elements is easily effected by a system of back-flushing or by removing the elements; the latter operation being easily accomplished owing to the functional design of the filter bodies.

Inset, the **Aerox** filter element

Compressed air filters fitted with *Porsilex* elements have been giving years of excellent service in the supply lines of pneumatic instruments and tools, air chucks, fly presses, rubber mixers, moulding machines, paint spray guns, riveters and similar machines. In addition they are used in the filtration of gases used in the production of high explosives, of hot aluminium fumes, hydrogen, carbonic acid, ammonia and steam.

Aerox Ltd, Lister Place, Hillington, Glasgow, SW2

Bolts are out in new scaffold system



Mills Scaffold Co Ltd, Trussley Works Hammersmith Grove, London, W6

A new type of steel scaffolding has recently become available in this country. The main feature of the system is the extreme speed with which it can be erected and dismantled. This has been achieved by doing away entirely with nuts, bolts or clips, the units slotting into one another with an extremely simple self-locking feature. Standard self-braced tubular steel panels are available in a variety of sizes and the system is completed by a range of portal frames, tie rods, braces, cantilevers, swivel jib and bases—stationary, jacking and castor.

Complete units to almost any size can be erected by only two men, one to handle the frames and the other to put them into position. When assembled, the whole structure is rigid and self-locked. As an example of the speed of erection, the manufacturers claim that an 18ft tower 5ft by 5ft can be erected by two men in 2½ minutes. The Mills Self-lock Scaffold should find considerable application in nuclear energy work—not only for new construction but also for temporary experimental or maintenance facilities of all kinds. The system is manufactured under Jagiel patents.

London Transformers repeat Calder order

The Calder auxiliary power transformers for l.t. supplies were designed and manufactured by London Transformer Products at their main works situated at Bridgend, Glamorgan, where units for the duplicate station are already under construction. The transformers comply with BS.171:1936 in all respects and are of the oil-immersed naturally-cooled type "ON", suitable for operation out of doors and to supply a mixed power and lighting load having a power factor of ·75 to ·8 lagging.

The complete installation consists of four units of 1250kVA, four of 750kVA and a single 150kVA unit, all designed to give continuous maximum output with the temperature rise limited to 50°C oil and 60°C windings, and suitable for parallel operation with others of the same output and characteristics.

All sizes of transformers operate from a 3-phase 3-wire 50 cycles supply, the neutral of which is earthed—11kV for 1250kVA and 3·3kV for 750 and 150kVA—and provide a 427 volt 3-phase, 4-wire supply on the secondary side.

The high voltage windings are delta connected and the low voltage windings star connected with the l.v. neutral brought out for earthing solidly.

Tappings are provided on the h.v. side to give ±2½, ±5 and ±7½ per cent of the service voltage for the 1250kVA size and ±2½ and ±5 per cent for the 750kVA and 150kVA sizes, selected by means of a manually operated off load switch.

Full routine and type tests in accordance with BS.171:1936 were carried out at works and the units were despatched complete with oil and fully assembled ready for immediate use after installation.

London Transformer Products Ltd, Cobbold Estates, Willesden, London, NW10

Glass now conducts electricity

Electrically-conducting glass has recently been perfected at the Sunderland works of the makers of *Pyrex* glassware, James A. Jobling & Co Ltd. The new glass is in the form of panels or tubes and is designed to provide resistance heating over an area or along a column. At an exhibition held recently in Sheffield, the new glass was shown in use on a fractional distillation column. It is the result of years of intensive research and development.

James A. Jobling Ltd, Wear Glass Works, Sunderland

On the travelling gantry spanning the pool, four control rods regulate the reactivity

Harwell's first pool reactor now working on shield studies

Firms cooperated to build Lido

The main purpose of the AERE's Lido pool reactor is the development of lightweight shielding for marine and other small reactors. LIDO (the name has no etymological significance) uses 3½kg of U235 in the form of 50 per cent enriched plate-type elements. There are 27 of these, each consisting of 13 plates formed from U-Al alloy clad in pure Al. There are 10gm of U235 in each plate. Light water is used as moderator, reflector, coolant and top shield. The peak neutron flux is 10^{12} n/cm²/sec and the maximum heat output is about 100kW—so that no special cooling arrangements are provided. The water is however demineralized and chlorinated.

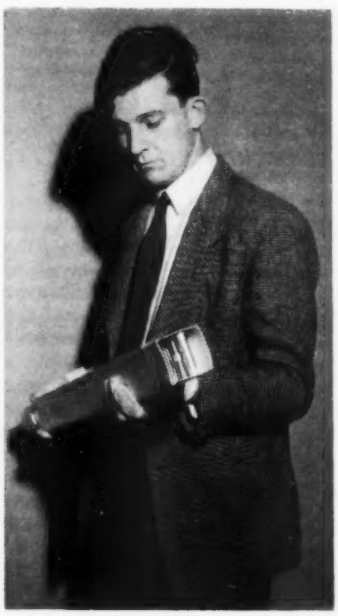
The core is suspended in an aluminium box structure from a trolley which can travel the length of the tank and also traverse

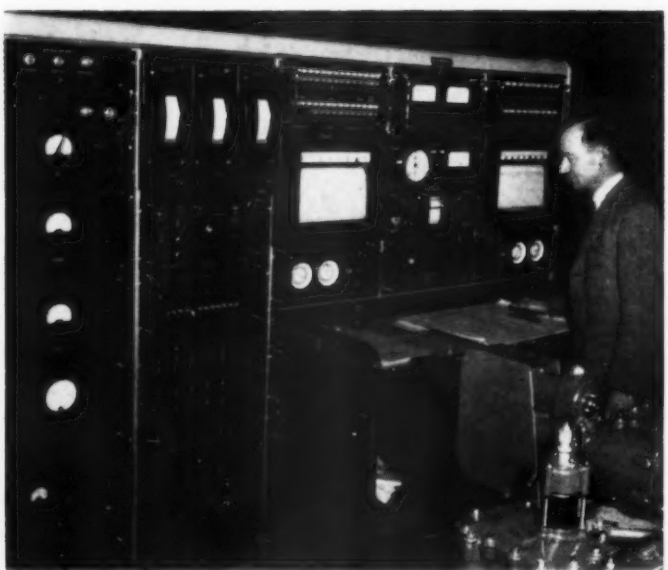
Illuminated by underwater lights, the core is below 17ft of water. In the dark, it can be seen by the Cherenkov radiation. Left, is the watertight door which seals off the handling bay

its width. One end of the tank is formed into a bay which can be isolated from the main pool by a watertight door, thus permitting access to the core. Control is by four rods in the form of cadmium-clad plates similar to fuel plates. One of these is for coarse control, one for fine control, and two for shut-down. These are actuated by rack-and-pinion gearing. The concrete wall of the pool in its lower part is very thick to provide biological shielding but is fitted with aluminium "windows" through which radiation is obtained when the core is brought alongside. In front of these windows is fitted the shielding or other experimental facility it is desired to test. The trolley is made movable so that while experiments are taking place at one 'window' other tests can be in course of preparation. When a window is not in use, it is sealed with concrete blocks. Lido was designed by a joint Admiralty-Harwell team in association with Vickers-Armstrongs (Barrow) Ltd (reactor components), Ericssons Telephones Ltd (instrumentation), Rolls-Royce Ltd (control gear), and Marston Excelsior Ltd (fuel elements). The buildings and reactor tank were constructed by the Ministry of Works under sub-contracts.

Photos: John Ross

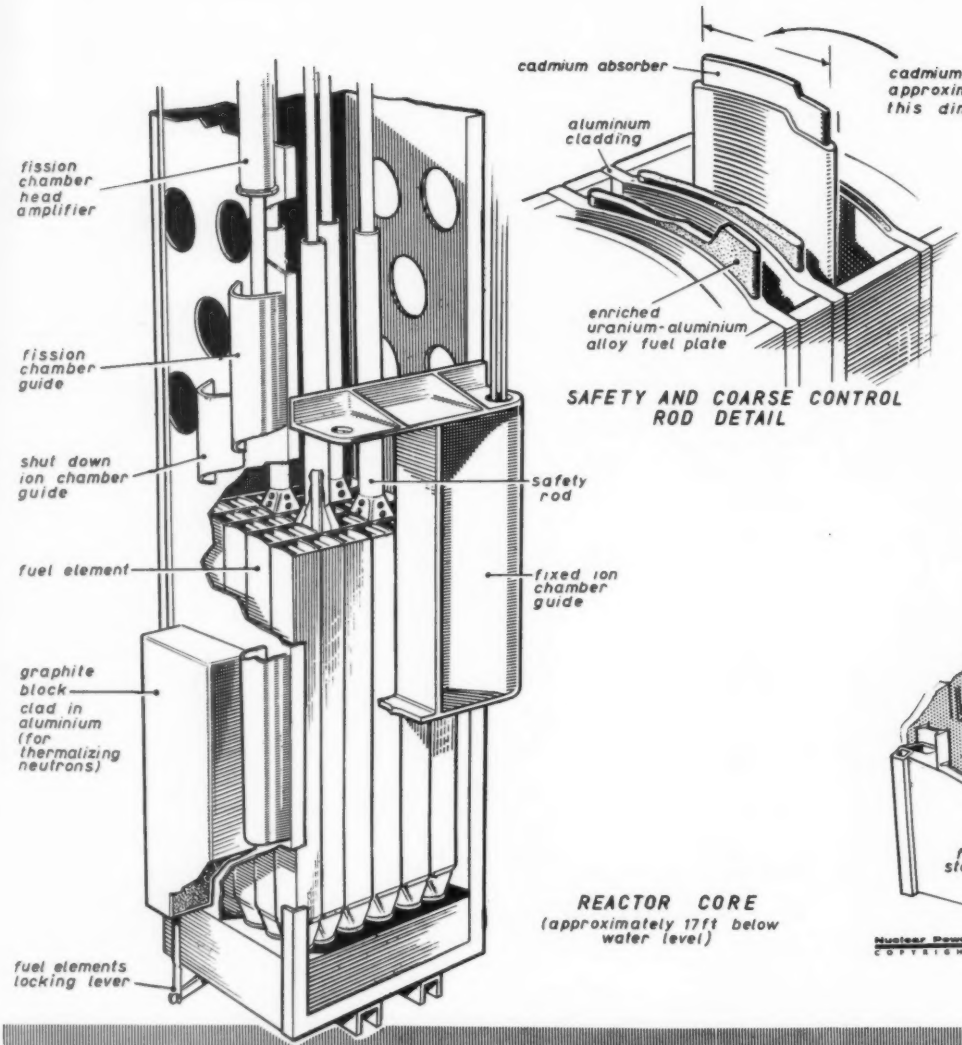
Lido's fuel elements are of the same general design as Dido's but there are 13 plates per box instead of 11 and the uranium is only 50 per cent enriched

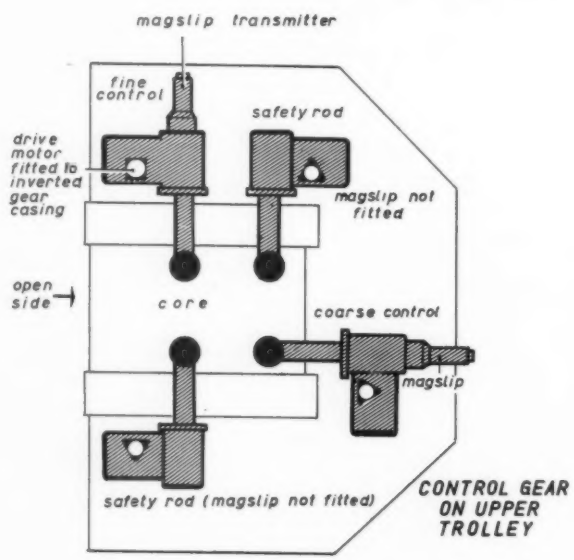


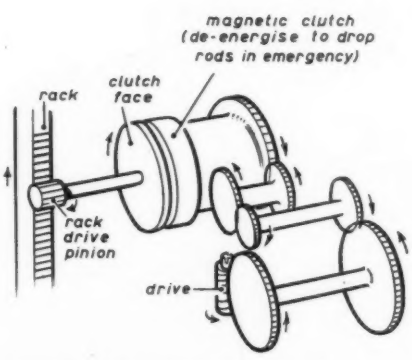


The control panel is also on the trolley and is equipped with a very comprehensive instrumentation layout

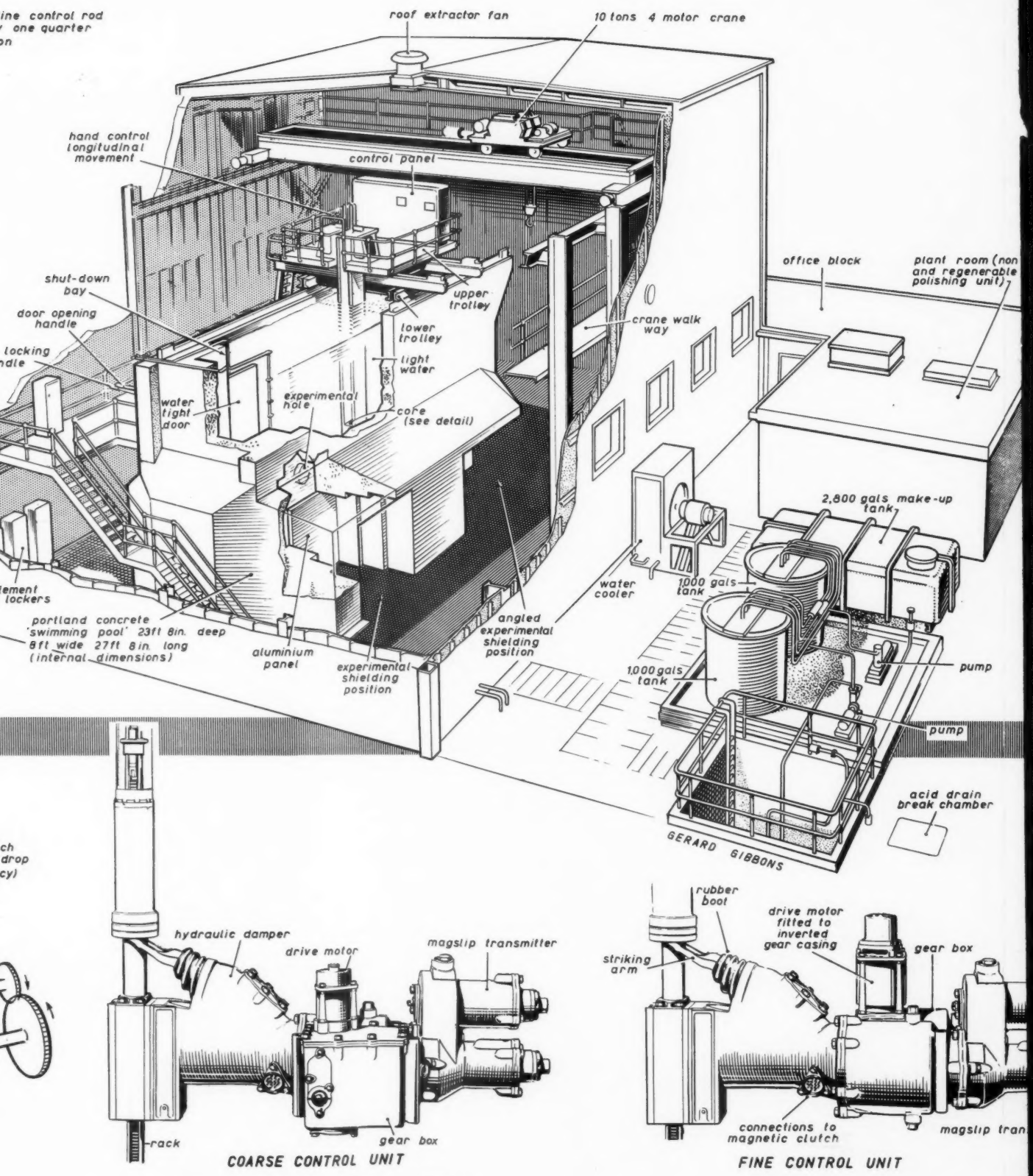
When not in use, the aluminium 'windows' of the pool are blanked off by massive concrete blocks. Here a research worker is monitoring the area


fission chamber head amplifier
fission chamber guide
shut down ion chamber guide
fuel element
graphite block clad in aluminium (for thermalizing neutrons)
fuel elements locking lever
safety rod
fixed ion chamber guide
cadmium absorber
aluminium cladding
enriched uranium-aluminium alloy fuel plate
cadmium in fine control
approximately one quarter
this dimension
SAFETY AND COARSE CONTROL ROD DETAIL
REACTOR CORE
(approximately 17ft below water level)
door opening handle
door locking handle
fuel element storage lockers
portland
swimming
8ft wide
(internal
Nuclear Power
COPYRIGHT

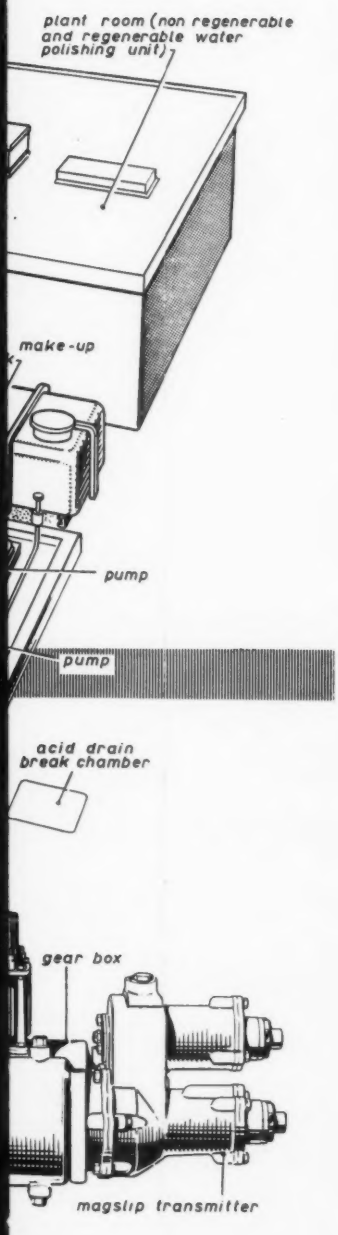

magslip transmitter
fine control
safety rod
drive motor fitted to inverted gear casing
magslip not fitted
open side
core
coarse control
magslip
safety rod (magslip not fitted)
CONTROL GEAR ON UPPER TROLLEY


magnetic clutch (de-energise to drop rods in emergency)
rack
clutch face
rack drive pinion
drive
GEAR TRAIN-CONTROL UNITS

Copies of this drawing may be obtained from *NUCLEAR POWER*, 3 Percy Street, London, W.1.



ercy Street, London, W.1, at a cost of 6d post free



LIDO

research reactor

ATOMIC ENERGY RESEARCH ESTABLISHMENT HARWELL

Reactor Physics - 9

James F. Hill, Senior Lecturer, Reactor School, Harwell

Fission product positions affect reactor performance: so does the temperature. This is explained in NUCLEAR POWER's basic course

1. Reactor operating at power

When a reactor is operated at power there are a consequent variety of effects and changes which take place in the reactor which mean that, in effect, the critical size of the reactor is constantly changing.

Among the changes which affect the reactor are:

1. the build-up of fission product poisons
2. temperature effects
3. density effects
4. pressure effects
5. changes in the content of fissionable material

These we shall discuss in turn.

2. The build-up of fission product poisons

As a reactor is run, fission products will build up. All these will absorb neutrons and so affect the multiplication constant of the reactor. However, most of the fission products will have a negligibly small effect on the value of k because their total cross-section is small. However, if a particular fission product (*i.e.*, either a primary fission product produced as a direct result of fission, or a daughter product of one of these) has a large yield (the maximum yield is of the order of 7% of fissions) and has a very high cross-section then it can have an appreciable effect on k. These fission products are called poisons because they poison the working of the reactor.

There are three types of fission-product poison which can be of consequence in reactor operation. The first type, of which the Xe^{135} isotope is an example, has a large cross-section and a large fission yield; it is also a radioactive substance and so undergoes radioactive decay as well as capturing neutrons. The second type—Sm^{149} is an example—also has a large cross-section and a large fission yield but, in this case, the poison is a stable isotope and so is only removed by capturing neutrons.

In both of these types, their effect is noticed after the reactor has been running for only a short time. The third type is only of interest where the effect on the reactor is required after a long irradiation (a long irradiation is a large value of the thermal neutron flux multiplied by the time). This is where the poison has not a very large yield or a very large cross-section but sufficiently large values of these quantities to have a significant effect on the value of k only after a long irradiation.

3. The effect on the multiplication constant of a reactor poison

As we have said, the effect of poisons is to absorb neutrons. Thus the effect on k can be considered as simply an effect on the thermal utilization f. Now the thermal utilization can be defined by the equation

$$\frac{1}{f} = \frac{\text{total absorption}}{\text{fuel absorption}} \qquad (9.1)$$

and if f_1 is the value of f with a poison present and f is the value without the poison present

$$\frac{1}{f_1} - \frac{1}{f} = \frac{\text{absorption by poison}}{\text{absorption by fuel}} \qquad (9.2)$$

so that if N_P and N_F are respectively the total number of poison and fuel atoms in the reactor and their absorption cross-sections are $\sigma(P)$ and $\sigma(F)$ then

$$\frac{f - f_1}{f f_1} = \frac{N_P \sigma(P)}{N_F \sigma(F)} \qquad (9.3)$$

But $f_1 - f$ is the change in the thermal utilization Δf_1, and if this change is small $f_1 \simeq f$ so that

$$\frac{\Delta f}{f^2} = -\frac{N_P \sigma(P)}{N_F \sigma(F)} = -\Delta\left(\frac{1}{f}\right) \qquad (9.4)$$

ON DISCUTE l'effet toxique des produits de fission sur le facteur de multiplication de réacteur et l'on envisage deux cas spéciaux. On démontre que l'isotope stable samarium-149 est produit de manière à atteindre une valeur constante indépendamment du flux. Dans l'autre cas, caractérisé par du xénon-135, le poison est radioactif et, par conséquent, la quantité d'équilibre actuelle dépend du flux. De plus, quand on ferme le réacteur, la quantité du poison xénonique continue a croître jusqu'à une valeur maxima qui, à son tour, dépend du flux.

Le fonctionnement du réacteur dépend aussi de température; pour le cas d'un réacteur thermique on considère la variation du Laplacien de réacteur avec température.

DIE AUSWIRKUNG von Vergiftung mit Spaltungsprodukten auf den Vermehrungsfaktor wird erörtert und es werden zwei Spezialfälle erwogen. Es wird gezeigt, dass ein stabiles Isotop, Samarium-149, sich unabhängig von dem Fluss bis zu einer konstanten Menge anhäuft. In dem anderen, durch Xenon-135 gekennzeichneten Fall dagegen ist das Gift radioaktiv, und die vorhandene Gleichgewichtsmenge hängt vom Fluss ab. Ausserdem, wenn der Reaktor ausgeschaltet wird, steigt die Xenongiftmenge weiter bis zu einem Maximalwert, der wiederum vom Fluss abhängig ist.

Die Wirkungsweise eines Reaktors hängt ebenfalls von der Temperatur ab; im Falle eines Wärmereaktors werden Veränderungen der Flusswölbung mit Temperatur erwogen.

EL EFECTO del envenenamiento del producto de fisión en la constante de multiplicación de un reactor es discutido y se estudian dos casos especiales. Se revela que el isótope estable, samario 149, se desarrolla hasta una cantidad constante, independiente del flujo. En el otro caso, tipificado por el xenón 135, el veneno es radiactivo y por lo tanto la cantidad de equilibrio presente depende del flujo. Además, al cerrar el reactor la candidad de veneno de xenón sigue aumentando hasta un valor máximo, que depende asimismo del flujo. La eficiencia de un reactor es también afectada por la temperatura y, en el caso de un reactor térmico, son considerados los cambios en el "buckling" con la temperatura.

ОБСУЖДАЕТСЯ ДЕЙСТВИЕ отравления продуктами деления на фактор размножения реактора и рассматриваются два особых случая. Доказывается, что, независимо от величины потока, постоянный изотоп самарий-149 накапливается до постоянного содержания. В другом случае, характеризуемом ксеноном-135, отрава радиоактивна, и поэтому наличное равновесное количество зависит от величины потока. Кроме того, при остановке реактора количество ксеноновой отравы продолжает увеличиваться до максимума, который в свою очередь зависит от величины потока.

Производительность реактора зависит также от температуры; для случая теплового реактора рассматривается изменение лапласиана с температурой.

Now consider the change in k caused by a change in f, then

$$\frac{\Delta k}{k} = \frac{\Delta f}{f} = - f \Delta \left(\frac{1}{f}\right) \tag{9.5}$$

So combining (9.4) and (9.5)

$$\frac{\Delta k}{k} = - f \left(\frac{N_P \sigma(P)}{N_F \sigma(F)}\right) \tag{9.6}$$

Thus, in order to calculate the change in k due to the build-up of a fission product poison we have to calculate the value of $N_P \sigma(P)/N_F \sigma(F)$. This we shall now do for the first two types of fission product poisons mentioned above.

4. Stable reactor poison: Sm^{149}

The isotope Sm^{149} is produced in the fission product chain

$$Nd^{149} \xrightarrow{1.7h} Pm^{149} \xrightarrow{47h} Sm^{149}$$

The times quoted are half-lives (see appendix).

The absorption cross-section for thermal neutrons of Sm^{149} is 5×10^4 barns and the fission yield (the percentage of fissions which yield the Nd^{149} isotope) of the chain is 1·4%. The decay of Nd^{149} into Pm^{149} is so rapid in terms of a reactor's life that we shall ignore it and simply consider the decay of Pm^{149} supposing that the Pm^{149} is formed directly on fission. We also suppose that the Pm^{149} cross-section is zero.

Using P and S respectively to denote the number of atoms of promethium and samarium in the reactor at time t, y the fission yield of Nd^{149}, λ the mean life of Pm^{149}, σ the absorption cross-section of Sm^{149}, and σ_f the fission cross-section of the fuel, then the rate of production of Pm^{149} is the flux multiplied by the total fission cross-section multiplied by the fission yield, so

$$\frac{dP}{dt} = \phi N_F \sigma_f y - \lambda P \tag{9.7}$$

and

$$\frac{dS}{dt} = \lambda P - \phi \sigma S \tag{9.8}$$

The solution of these equations for S gives, as $P = S = 0$ at $t = 0$

$$S = \frac{N_F \sigma_f y}{\sigma(\phi\sigma - \lambda)} \left\{ \phi\sigma \left(1 - e^{-\lambda t}\right) - \lambda \left(1 - e^{-\phi\sigma t}\right) \right\} \tag{9.9}$$

and the equilibrium number of samarium atoms S_∞ is got at by putting $t = \infty$ in (9.9) so

$$S_\infty = N_F \sigma_f y / \sigma \tag{9.10}$$

and then

$$\frac{S}{S_\infty} = \frac{1}{\lambda - \phi\sigma} \left\{ \lambda \left(1 - e^{-\phi\sigma t}\right) - \phi\sigma \left(1 - e^{-\lambda t}\right) \right\} \tag{9.11}$$

In practice, of course, the samarium builds up almost to its equilibrium in a time which is long compared to $1/\phi\sigma$, the rate of build up depending on the value of the flux. In a flux of 10^{13} neutrons per cm^2 per sec. $1/\phi\sigma = 23{\cdot}2$ days and then after 100 days in this flux $S/S_\infty = 0{\cdot}985$, that is, the samarium has reached 98·5% of its equilibrium value.

For the effect on k in equilibrium (9.10) is substituted in (9·6) putting $N_P \sigma_P = S_{P\infty} \sigma$, and so

$$\Delta k / k = - f y \sigma_f / \sigma(F) \tag{9.12}$$

It is to be noted that this is independent of the flux, so that the equilibrium value of the samarium poison is independent of the flux in the reactor.

For natural uranium and putting $y = 1{\cdot}4\%$, (9.12) becomes

$$\Delta k / k = - 0{\cdot}0076 f \tag{9.13}$$

5. Unstable reactor poison: Xe^{135}

The chain in which Xe^{135} occurs is

$$Te^{135} \xrightarrow{2m} I^{135} \xrightarrow{6{\cdot}7h} Xe^{135} \xrightarrow{9{\cdot}2h} Cs^{135} \xrightarrow{2 \times 10^4 y} Ba^{135} \text{ (stable)}$$

As the half-life of Te^{135} is so short compared to any time we are concerned with in reactor poisons and as the Cs^{135} is so long lived compared with any reactor lifetime, we shall consider only the chain

$$I^{135} \longrightarrow Xe^{135} \longrightarrow Cs^{135} \text{ (assumed stable)}$$

Then using a similar notation as for samarium, supposing the I^{135} to have negligible cross-section

$$\frac{dI}{dt} = \phi N_F \sigma_f y - \lambda_I I \tag{9.14}$$

$$\frac{dX}{dt} = \lambda_I I - \lambda_X X - \phi\sigma X \tag{9.15}$$

If we put

$$\lambda_X' = \lambda_X + \phi\sigma \tag{9.16}$$

Then (9.15) becomes

$$\frac{dX}{dt} = \lambda_I I - \lambda_X' X \tag{9.17}$$

and (9.14) and (9.17) are then similar to (9.7) and (9.8), the solution for X, with $I = X = 0$ at $t = 0$ being

$$X = \frac{N_F \sigma_f y \phi}{\lambda_X' (\lambda_X' - \lambda_I)} \left\{ \lambda_X' \left(1 - e^{-\lambda_I t}\right) - \lambda_I \left(1 - e^{-\lambda_X' t}\right) \right\} \tag{9.18}$$

and

$$\frac{X}{X_\infty} = \frac{1}{\lambda_X' - \lambda_I} \left\{ \lambda_X' \left(1 - e^{-\lambda_I t}\right) - \lambda_I \left(1 - e^{-\lambda_X' t}\right) \right\} \tag{9.19}$$

where the equilibrium value of X, X_∞ is given by

$$X_\infty = N_F \sigma_f y \phi / \lambda_X' \tag{9.20}$$

which is now a function of the flux. Thus in the case of the unstable poison both the rate of build-up and the equilibrium value depend on the flux.

Because the half lives concerned are much shorter in the xenon case the xenon poison builds up much quicker than the samarium.

The equilibrium effect on k is got by substituting (9.20) into (9.6) giving

$$\frac{\Delta k}{k} = - f y \frac{\sigma_f}{\sigma(F)} \cdot \frac{\phi\sigma}{\lambda_X'} \tag{9.21}$$

or

$$\frac{\Delta k}{k} = - \frac{f y \sigma_f / \sigma(F)}{1 + \lambda_X' / \phi\sigma} \tag{9.22}$$

For Xe^{135}, $\sigma = 3{\cdot}2 \times 10^6$ barns and $y = 5{\cdot}6\%$* so substituting these values into (9.22) gives

$$\frac{\Delta k}{k} = - 0{\cdot}544 f / 1 + \frac{6{\cdot}54}{\phi \times 10^{-12}} \tag{9.23}$$

On shutting down a reactor any fission product poison which is not a primary fission product will increase

* There is also some production of Xe^{135} as a direct fission product whose yield is 0·3%. We shall not take account of this here.

initially. This can be seen by considering the particular case of Xe^{135}, though it applies equally well to Sm^{149}. The Xe^{135} is produced as a result of the decay of I^{135} and when the reactor is shut down the production of I^{135} ceases immediately (assuming ϕ becomes zero) but the decay of I^{135} continues, and furthermore continues initially almost at the same rate. This means that initially the Xe^{135} continues to be produced almost at the same rate. But Xe^{135} is removed by radioactive decay and by neutron capture in general, but if the flux becomes zero the xenon ceases to be removed by neutron capture. Thus its rate of removal decreases. Now in equilibrium the rate of production is equal to the rate of removal and so on shutting down, initially, the rate of production exceeds the rate of removal and so the number of Xe^{135} atoms starts to increase.

Eventually the rate of decay of iodine starts to decrease and so the number of Xe^{135} atoms reaches a maximum and then starts to decrease and eventually drops to zero, if the reactor is not started up again.

The amount by which the xenon builds up and the time at which the maximum build-up occurs after shutdown depends on the neutron flux. This dependence can be seen from the equations below.

Suppose now we consider the problem of shutting the reactor down when the I^{135} and Xe^{135} are in equilibrium. Then at $t = 0$, $I = I_\infty$, $X = X_\infty$ and we put $\phi = 0$ in (9.14) and (9.15). This gives

$$\frac{dI}{dt} = -\lambda_I I \tag{9.24}$$

and

$$\frac{dX}{dt} = \lambda_I I - \lambda_X X \tag{9.25}$$

where t is measured from the time of shut-down. These give

$$\frac{X}{X_\infty} = \frac{1}{\lambda_X - \lambda_I}\left|\lambda_X' e^{-\lambda_I t} - \lambda_I' e^{-\lambda_X t}\right| \tag{9.26}$$

where for convenience we have defined λ_I' by

$$\lambda_I' = \lambda_I + \phi\sigma \tag{9.27}$$

The time t_m at which X is a maximum is given by

$$t_m = \frac{1}{\lambda_X - \lambda_I} \ln \frac{\lambda_I' \lambda_X}{\lambda_X' \lambda_I} \tag{9.28}$$

and X_m the maximum value of X by

$$\frac{X_m}{X_\infty} = \frac{\lambda_X'}{\lambda_X} \exp\left(-\lambda_I t_m\right) \tag{9.29}$$

Both t_m and X_m increase with the flux but there is an upper limit to the value of t_m obtained by putting $\phi = \infty$ in (9.28). This gives

$$t_m \ (\phi = \infty) = 11{\cdot}3 \text{ hours} \tag{9.30}$$

The effect on k after shut-down can be found by combining (9.26) with (9.20) and (9.6) and is here a function of the time.

This effect whereby the xenon poison increases on shut-down on the reactor affects the operation of a reactor. For it means that if it is required to start up the reactor at any time after shut-down there will have to be available in the reactor sufficient amount of excess reactivity to overcome the additional xenon poison. As this amount can be very large it may be necessary in a particular reactor to forego this requirement and only arrange that the reactor can start up a given time after shutdown either before the xenon poison has built-up to a particular value or after it has died away to this value.

It should be remembered that the Sm^{149} also builds up on shutdown. In this case it builds up to a higher constant value as it does not decay radioactively, and on start up returns to its equilibrium value again. However, this build-up is relatively small compared with the xenon case and can be disregarded in general except for extremely high fluxes much greater than 10^{14} neutrons per cm^2 per sec. X/X_∞ is plotted as a function of the time for various fluxes in Figure 9.1.

6. Temperature effects

If the temperature of a reactor is changed there are three types of effect which occur.

The main effect is that the thermal neutron temperature (or energy) changes and so the cross-sections of the materials of the reactor change. This means that the buckling changes and so is a function of the temperature. Also the dimensions of the reactor and its components will change due to expansion or contraction. This also means that the density of the materials change and so the mean free paths of the materials also change. For the type of reactor we are discussing here (large thermal reactors) these latter effects are small, with the exception that if the reactor contains a fluid the change in density of the fluid may in fact contribute an appreciable effect. Thus the effect of temperature on a reactor can be thought of as change both the components of k and also the diffusion and slowing down lengths.

It is usual in a reactor to lump all temperature effects together and treat them as if they cause changes in the effective multiplication constant of the reactor—thus together taking account of changes in k and of L^2 and L_s^2. Expressed as a change in k_e per degree centigrade this is then known as the temperature coefficient of the reactor.

The temperature coefficient has an important bearing on the operation of a reactor. If the coefficient is negative, that is, the reactivity decreases as the temperature increases, this acts as a safety device on the reactor. Because, if the reactor power should rise for any cause the reactor temperature will rise and so the reactor tends to shut itself down. If the situation were reversed then a reactor would be extremely difficult to control.

7. Changes in the effective multiplication constant

We can say immediately that there will be no change in the fast fission factor ε with temperature. This is because only fast neutrons are involved and temperature changes in the reactor will not affect the fast neutron energies.

The resonance escape probability p is decreased as the temperature of the uranium in a reactor increases. This effect is not a simple one and arises from the fact that if the temperature is increased the uranium atoms vibrate more quickly and this has the effect of making the neutron resonances in the U^{238} appear wider to the slowing-down neutrons. They are thus captured more easily and so p decreases as the temperature increases and hence there is a negative effect on the reactivity. This effect, then, depends only on the fuel temperature. The *temperature* of the neutrons is governed by the moderator temperature because in a thermal reactor the moderator forms the major bulk of the lattice. So the neutrons are in thermal equilibrium with the moderator atoms. Because of this there is a change in the thermal

utilization, f, with moderator temperature. This is simply illustrated by considering the lattice to consist of fuel and moderator only. Then f is defined as $f =$

$$\frac{(N\sigma V)_F \bar{\phi}_F}{(N\sigma V)_F \bar{\phi}_F + (N\sigma V)_M \bar{\phi}_M} = \frac{1}{1 + \dfrac{(N\sigma V)_M \bar{\phi}_M}{(N\sigma V)_F \bar{\phi}_F}} \quad (9.31)$$

where M represents the moderator, $\bar{\phi}$ the average fluxes, and σ the absorption cross-sections. Now in the thermal region, most absorption cross-sections vary inversely with the neutron speed. So, if the lattice was a homogeneous mixture, that is $\bar{\phi}_F = \bar{\phi}_M$ there would be no variation of f with temperature as $(N\sigma V)_M$ and $(N\sigma V)_F$ change by the same fraction. However, in a heterogeneous arrangement $\bar{\phi}_F$ and $\bar{\phi}_M$ are not equal and if the temperature increases, the neutron energy and speed increase and so the cross-sections decrease. This means that the neutrons travel further before being absorbed and this has the effect of making $\bar{\phi}_F$ and $\bar{\phi}_M$ more nearly equal to each other. (In the extreme, if the cross-sections became zero there could be no variation in ϕ so then $\bar{\phi}_F$ and $\bar{\phi}_M$ would be equal.) This effect is known as the *levelling effect.*

Then $\bar{\phi}_M / \bar{\phi}_F$ decreases as the temperature increases and so f increases as the temperature increases.

We have said above that in the thermal region absorption cross-sections vary inversely with the neutron speed. If this was strictly true then η, the number of neutrons per neutron absorbed, would not depend on the temperature as η defined as

$$\eta = \frac{\nu N_{\sigma f}}{N\sigma_f + N\sigma(F)} \quad (9.32)$$

ν the number of neutrons per fission is not dependent on the temperature and the variations in the cross-section cancel out.

However, for uranium the cross-sections do not vary exactly inversely as the speed and so η does in fact change with temperature. For uranium, in fact, in the thermal region, η decreases with temperature and again this depends on the moderator temperature.

The value of k_e also depends on the slowing-down and diffusion length in a reactor. The change in the slowing-down length with temperature is small as an increase in temperature only very slightly decreases the total slowing-down energy range from 2 MeV to thermal.

The diffusion length, however, is changed by a much larger amount. As the temperature increases all the absorption cross-sections decrease and so the diffusion length will increase. This means that the leakage is increased and so k_e is decreased.

Taking all these factors into account will lead to a negative temperature coefficient and for a typical graphite uranium reactor such as Bepo the overall temperature coefficient is $-2{\cdot}8 \times 10^{-5}$ in k_e per degree Centigrade.

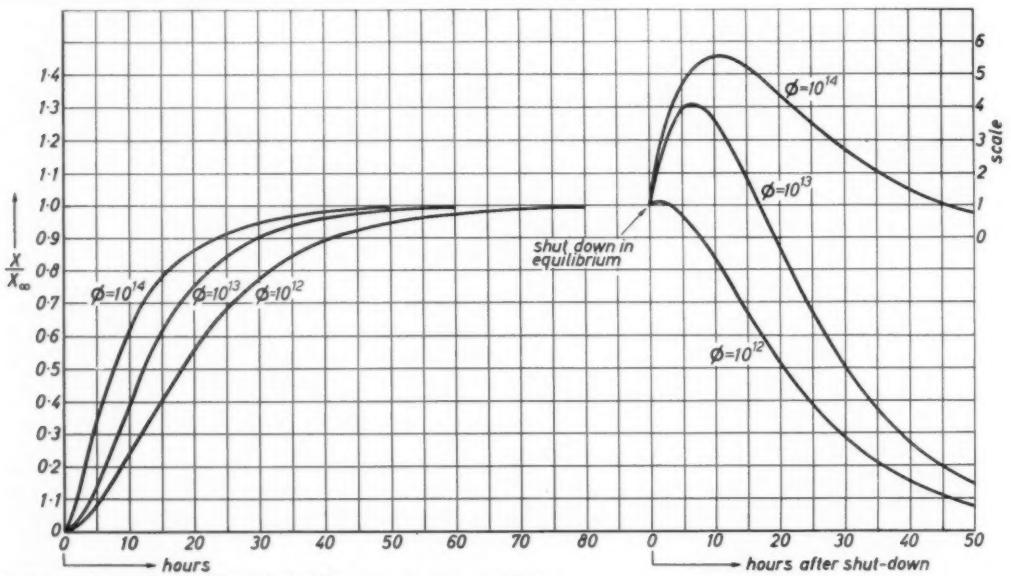


Fig. 9.1 The ratio of the number of Xe-135 atoms to the equilibrium number when building up to equilibrium and on shutting down the reactor

APPENDIX: THE LAWS OF RADIOACTIVITY

If a nucleus is unstable and spontaneously emits either an α-particle (the nucleus of a He^4 atom) or a β-particle (an electron) it is said to be radioactive. There is one general law of radioactive decay which states that the chance that a particular nucleus will decay in unit time is constant. Thus if P is the number of radioactive nuclei of a given type present at time t, then

$$\frac{1}{P}\frac{dP}{dt} = \text{constant} \quad (A.9.1)$$

and if we set the constant equal to $-\lambda$ (because λ can then be a positive quantity as P must decrease with t), then

$$\frac{dP}{dt} = -\lambda P \quad (A.9.2)$$

or

$$P = P_0 e^{-\lambda t} \quad (A.9.3)$$

where P_0 is the number of nuclei of P present at $t = 0$.

The constant λ is called the decay constant, and λ^{-1} is equal to the mean lifetime of a nucleus.

The quantity usually used to specify the rate of radioactive decay is the half-life T. This is defined to be the time after which half the atoms will have decayed and is related to λ from (A.9.3) by

$$T = \frac{ln\ 2}{\lambda} = \frac{0{\cdot}6931}{\lambda} \quad (A.9.4)$$

Next month's instalment will deal with density and pressure effects and with the changes in fissionable material content

CIVIL ENGINEERS FOR APC

The well known civil engineering contractors, Trollope and Colls Ltd, in association with Holland & Hannan and Cubitts Ltd, are to carry out the building, civil engineering and structural work for the new nuclear group—Atomic Power Constructions Ltd—whose formation was announced last month. Trollope and Colls Ltd have considerable experience in this class of work, having been engaged as main contractors for seven years on the construction of the Windscale plutonium plant, the uranium factory at Springfields and the gaseous diffusion plant at Capenhurst.

So far, the APC have not announced any new plans but presumably they will be tendering for future stations.

AEI-JT-MORGAN LINK UP

Before leaving for Canada last month, AEI chairman Lord Chandos announced the formation of a new company in conjunction with the Morgan Crucible Co Ltd. This is known as Nuclear Graphite Ltd and it will specialize in the machining of graphite blocks for the moderator used in the Calder type power station. Although not at present a producer of reactor grade graphite, Nuclear Graphite Ltd is prepared to machine blocks for any group. Chairman of Nuclear Graphite is Mr Harry West—managing director of AEI-John Thompson Nuclear Energy Co Ltd. The managing director is Mr R. S. Silman of Morgans and the other directors are J. H. N. Thompson of John Thompson Ltd; G. S. C. Lucas of British Thomson-Houston and C. J. Hewes and G. M. Slight of Morgan Crucible. Morgans have just completed the manufacture and machining of the graphite blocks used in the Dounreay fast breeder reactor, but these are for the neutron shield and are not of moderator-grade.

Speaking of his trip, Lord Chandos said Britain was now in a commanding position regarding export of nuclear power stations and he felt that although the Canadians were concentrating on heavy-water reactors, they might still find that the graphite pile offered an attractive proposition. He considered that industrial countries like Canada, Japan, Italy and Germany would not be interested in complete power station packaged deals 'down to the last door knob' since they have the ability to carry out much of the work themselves, provided they have the knowhow. It is in this knowhow together with specialized equipment such as control gear, gas blowers, fuel charging, graphite blocks etc. where Britain's best hope lay, he continued.

The AEI-JT group have now formed an export department and Lord Chandos' mission was to act as a spearhead to develop this side of his business. The group is now prepared to supply not only complete research reactors, and large or small power reactors (below 75MW), but also specialized components and knowhow to any country able to carry out much of the largely conventional work themselves. During his stay in Canada, Lord Chandos is having conversations with Mr C. D. Howe, Minister of Trade and Commerce, Mr J. Duncan, Chairman of Ontario Hydro, and Mr A. Savoie, chairman of Quebec Hydro. Later, he will go to the United States for talks with GE and other bodies.

Asked at his press conference whether he thought a power cable connecting Northern Ireland with the British Grid might not be preferable to Ulster setting up her own nuclear power stations, Lord Chandos said he believed this was not an economic proposition at present.

Mr Howard A. Acheson (second from right) opens new plant in Scheemda

BERKELEY CONTRACT for PALMERS

Contracts for the whole of the constructional steelwork for the AEI-JT station at Berkeley have been given to the construction steel division of the Palmers Hebburn works of Vickers-Armstrong (Shipbuilders) Ltd. Palmers have produced constructional steelwork since 1935, and have played a considerable part in the post war extensions which have taken place throughout Britain in the drive for increased production, particularly in chemical engineering, shipbuilding, coal, motor car and other major industries.

BALDWIN REGISTER 'ATOMAT'

The name *Atomat* has always been associated with the range of nucleonic thickness gauges made by Baldwin Instrument Co Ltd, Dartford, Kent. It has now been registered as a trade mark—no 755,154—and will be applied to Beta, Gamma, Bremsstrahlung and X-ray thickness gauges as well as to the Transverse Profiler.

NEW ACHESON PLANT IN HOLLAND

The Acheson Colloiden NV plant at Scheemda, in the province of Groningen, Netherlands, is now in production. The factory, the first Acheson unit to be established on the continent of Europe since World War I, was officially opened by Mr Howard A. Acheson, President of Acheson Industries Inc, when he set in motion one of the machines used in the manufacture of colloidal graphite and other *dag* dispersions. With the President at the opening ceremony were Mrs Howard Acheson and the Managing Director of Acheson Colloids Ltd, Mr E. G. Clarke.

At an informal gathering following the ceremony, attended by representatives of the Press, the municipality and local industry, Mr Acheson praised all who had enabled the factory to be completed so quickly. In February the site was bare; by November a pleasing modern factory with spacious offices and laboratory had been built.

Mr Acheson expressed gratitude for the magnificent cooperation of the Scheemda community, both municipal and industrial. He confidently expected the new Company to maintain and develop the cordial relationships it had already established.

Four members of the staff of Acheson Colloids Ltd have been appointed to key positions at Scheemda. They are Mr G. J. Bennington Davies (General Manager), Mr A. D. Wright (Sales Manager), Mr M. A. Schrikker (Commercial Manager) and Mr R. English (Production Manager).

BORAX PRICE PEG

In common with many other industries the borax industry expresses great concern at the continued increase in shipping and transport costs. In August, Borax Consolidated Ltd announced they would hold their prices firm in this country from Oct 1, 1956, to March 31, 1957, unless exceptional factors intervened.

Since then, events in the Middle East have led to an increase in domestic delivery costs here which, although serious, is far overshadowed by the alarming rise in ocean shipping freights. These factors, coupled with an increase in American domestic and export prices, would normally have meant an increase of £3-£3 10s. per ton in the company's UK prices.

In spite of this, Borax have now announced that they still intend to hold their prices in the UK firm to March 31, 1957, unless altogether exceptional factors make this impossible. This is a practical example of the present cost to one industry of price stabilization, as well as an indication of the company's determination to continue support for the appeal for price restraint made by the Government and by the Federation of British Industries.

Borax have recently acquired research laboratories at Tolworth, in Surrey, to provide facilities for a staff of 50 chemists or more. Prior to January 1, when the move to Tolworth was completed, research was carried out in the relatively small laboratories at Borax House in Carlisle Place, London SW1.

MICANITE MANAGER RETIRES

Mr R. F. Mayne has retired from the Micanite & Insulators Co Ltd after 40 years service in their mica department of which he was manager for all but six. He is succeeded by Mr A. W. Townsend who has been his assistant for 26 years.

To mark the occasion Mr Mayne was presented with a cheque from the directors (presented by Mr H. A. Cooper Director and Joint General Manager), a fishing rod from the M & I Foremen's Association (presented by Mr D. J. Greene President of the Association) and a convector heater from the M & I Long Service Association (presented by Mr S. W. Messent Vice-Chairman of the Association).

Mr Mayne served for many years on the Management Committee of the Mica Trade Association.

KH EXHIBITS AT DUBLIN

At the Royal Dublin Society Exhibition, to be held from February 18-25, Kelvin and Hughes (Industrial) Ltd, through their agents, Hughes and Coyle of Dublin, will be showing several instruments of interest to atomic energy applications. These will include: *the Mk 5 ultrasonic flaw detector*—a miniature instrument; *the Mk 2 depth and thickness gauge*—an ultrasonic device used when access to only one surface is possible; *the Mk 2 four-pen high speed recorder*—used for recording transient phenomena hitherto only recordable by oscilloscope and photography; a single channel dynamic strain equipment for recording rapidly fluctuating strains, displacements, accelerations, pressures, flow, etc.

KENT APPRENTICE PRIZES

Applause from a large audience of distinguished visitors, parents and friends endorsed the thanks expressed by Commander P. W. Kent, RN (Retd), chairman and managing director of George Kent Ltd, to Sir John Burgoyne, OBE, JP, for his address as guest speaker at George Kent Ltd's Annual Apprentice Prize giving at Luton on January 7.

During 1956, Kent's had 127 apprentices under training. The winners of the first prizes in each group were: *The Commander Kent Challenge Cup*: J. C. Keeling; *The Sir Walter Kent Prize*: E. L. Amiss; *The R. W. Bedford Challenge Cup*: R. Stratford; *The Grout Prize*: M. J. Mansbridge. The prizes were presented by Commander Kent.

So many apprentices qualified for the Attendance Prize, that they had to

Commander P. W. Kent (left) presents a prize

assemble in two ranks in front of the dais to receive their awards. That so large a number should win this prize was particularly gratifying as, during 1956, not only had the apprentices to maintain 100 per cent attendance and punctuality at school, as in previous years, but at work also. This extra requirement surprisingly coincided with an increase in the number of apprentices qualifying, from 28 in 1955 to 47 in 1956. An Exhibition of apprentices' work, including hobbies, held in conjunction with the prize giving, attracted considerable attention.

SHORT COMPUTERS FOR EXPORT

Analogue computers designed and built by Short Bros & Harland Ltd, Belfast, were demonstrated to leading German and Swedish engineers and mathematicians in Brunswick last month. Among those present at the Brunswick Technical College were representatives of Berlin Technical University, Göttingen University and Hanover Technical College. Dr Horst Herrmann, distinguished German scientist, who is engaged on research at the Institute of Applied Mathematics at Brunswick, was instrumental in arranging the demonstration and before asking that the Short computer be sent, he had examined all types available, including British, French and American makes.

On leaving Brunswick, the computer was shipped to Stockholm for a demonstration by the Stockholm firm, Stenhardt Ingeniörsfirma AB, who have invited Swedish universities and colleges to submit special problems. The firm will also demonstrate the computer to the Swedish Government and a number of industrial establishments.

Shorts claim to be now Europe's leading manufacturers of analogue computers. Nearly thirty are already in use, and are proving particularly valuable in the aircraft industry, where they are applied mainly to investigation of aircraft flutter problems and stability of large aircraft.

NEW GEC POST FOR R. N. MILLAR

The General Electric Co Ltd announces that Mr R. N. Millar has been appointed assistant general manager of Fraser and Chalmers Engineering Works, Erith, as from Jan 1, 1957.. He will continue to be manager of the GEC Simon-Carves Atomic Energy Group which is centred at Erith.

Mr Millar was chief mechanical engineer to the British General Electric Co in Australia from 1952 to 1954, having previously been assistant mechanical engineer to the British General Electric Co in South Africa.

IN BRIEF

Pollard Bearings Ltd have opened a new London office at 44 Hertford St, W1 (Grosvenor 1402).

Head Wrightson Export Co Ltd, a subsidiary of Head Wrightson and Co Ltd of Thornaby-on-Tees have opened an office in Calcutta at 21 Netagi Subhas, Calcutta 1.

Whitehouse Industries Ltd have opened a new office for their *Philidas* division at 44 Hertford St, W1 (Grosvenor 1402). In addition to the standard range of Philidas lock-nuts for the aircraft and engineering industries, the range of products is now to include parts to AGS specifications.

New Metals & Chemicals Corporation, Tokyo, have moved to more spacious offices at Kankoji-Kaikan Bldg, 3, Ginza Nishi, 8-chome Chuo-ku, Tokyo. Their PO Box Central 565 and cable address NEMECHEM, Tokyo remain unchanged. They are the correspondents in Japan of New Metals & Chemicals Ltd, 16 Northumberland Avenue, London, WC2.

ERRATA

In our article **The food scientist looks at radiation protection** by R. S. Hannan and B. Coleby in our January issue an error occurred in the third paragraph (p 8). The sixth line should read 'almost a quarter of the annual volume . . .' (not 'an eighth').

In the table on p 12—**Uranium ores: their occurrence and treatment**—the tenth mineral should read THUCHOLITE.

WPC BELGRADE MEETING

A sectional meeting of the World Power Conference is to be held in Belgrade, Yugoslavia, during June 5-11 after which there will be a series of study tours. Seventeen papers are to be submitted by the British National Committee. These have been prepared by a committee under the chairmanship of Sir Josiah Eccles, Deputy Chairman (Ops), Central Electricity Authority. Among the British contributions will be:

Power supply and national production R. Y. Sanders, Deputy Chief Commercial Officer, CEA; *Investment in power in underdeveloped countries* G. H. Daniel, Under Secretary, MoP, and E. A. G. Robinson, Professor of Economics, University of Cambridge; *Economic factors affecting the establishment of a nuclear power industry in underdeveloped countries* J. A. Jukes, Economic Adviser, UKAEA; *A theoretical approach to the integration of hydroelectric and thermal power plants* J. Henderson, Chief Engineer, South of Scotland Electricity Board; *Design problems for nuclear power plants* H. S. Arms, Project Manager, English Electric/Babcock & Wilcox/Taylor Woodrow Atomic Power Projects; *Steam and power generation in the metallurgical, chemical and allied industries* G. Cooke, Chief Engineer (Power Plant) Simon-Carves Ltd.

GRAPHITE CONFERENCE IN SEPT.

The Society of Chemical Industry is to hold a conference on *Industrial Carbon and Graphite*, at the William Beveridge Hall, London University, on September 24, 25, 26, 1957. Papers will be presented by specialists from Britain, France, Germany, USA, Russia and other countries. The conference will be divided into three major sections as follows:—

STRUCTURE AND PROPERTIES: Physical and chemical properties; crystal structure; pores; surface properties; thermodynamic aspects; electrical characteristics.

PREPARATION: Raw materials; manufacturing processes; plant; new techniques and developments.

APPLICATIONS: Chemical; electrical; metallurgical; mechanical; *nuclear engineering.*

It is expected that titles of papers to be presented will be published in the Spring, these being pre-printed before the conference. The Honorary Secretary of the conference is Mr E. A. Smith, Acheson Colloids Limited, 18 Pall Mall, London, SW1 (Whitehall 2034-7).

BOT SET UP INSTRUMENT COMMITTEE

The prospects are that our external trading account will still be roughly in balance for the twelve months to April 1957, said Mr F. J. Erroll, MP, at that time Parliamentary Secretary to the Board of Trade, at the Annual Luncheon in London on January 8 of the British Industrial Measuring and Control Apparatus Manufacturers' Association (BIMCAM). He pointed out that after a difficult 1955, the year 1956 had shown a healthy improvement. For the first 11 months, imports were only one per cent higher in value than in 1955, while exports were six per cent higher in volume and ten per cent higher in value.

Mr Errol emphasized the achievements of Britain, mentioning the speed records on land, sea and air; the altitude record in flying; and the work done by British science and technology in splitting the atom, and, leading from that, the building of the first commercial nuclear power station at Calder Hall.

BIMCAM members played an important part in direct exporting and in promoting the efficiency of other exporting industries by means of their products. Nuclear plants could not be operated without a full range of control instruments.

The Board of Trade had recently set up an Instrument Industry Advisory Committee, which was due to meet for the first time this year. He was confident that this new body would provide a most useful liaison between the industry and the Government.

Mr R. G. Kent, BIMCAM chairman, referred to the formation by the Association of an Education Committee, which should result in material advances in technical education in the field of industrial instruments. He paid a tribute to Mr L. S. Yoxall, President of BIMCAM, who is chairman of the Joint Committee responsible for the Instruments, Electronics and Automation Exhibition to be held in London in May. They looked forward to a great success for this Exhibition.

BNEC ADMITS METALLURGISTS

The Iron and Steel Institute and the Institute of Metals were admitted as members of the British Nuclear Energy Conference at the BNEC's board meeting under the chairmanship of Sir John Cockcroft OM on Jan 9.

The announcement making this news also disclosed that the BNEC's symposium on Calder Hall, last November was attended by 1,800 delegates from countries throughout the world.

SCALING-UP CHEMICAL PLANT

A joint symposium of Het Koninklijk Instituut van Ingenieurs (Chemical Engineering Group), De Koninklijke Nederlandse Chemische Vereniging (Section for Chemical Technology), The Society of Chemical Industry (Chemical Engineering Group) and The Institution of Chemical Engineers will be held at Church House, Westminster, London SW1, on Tuesday, May 28 and Wednesday, May 29, 1957.

There will be morning and afternoon sessions each day for the presentation and discussion of papers. The programme will cover a wide range and will deal with the theoretical, practical and economic aspects of scaling-up. The collected papers will represent the greatest available concentration of information on the subject and it is anticipated that the proceedings of the symposium complete with discussions will provide a standard work of reference for chemical engineers for many years. Full details may be obtained from the sponsoring institutions.

OBITUARY

HAROLD JOHN FREDERICK GOURLEY

Six weeks after receiving the highest accolade of the engineering profession, in being elected President of the Institution of Civil Engineers, Mr Harold John Frederick Gourley, senior partner of Messrs Binnie, Deacon & Gourley, Consulting Engineers, who had entered Guy's Hospital during the course of the morning of December 18, died there that night at 6.30 p.m. He was one of the country's foremost water engineers. Mr Gourley was born in Liverpool in 1886 and educated at the Liverpool Institute before passing on to that City's University where in 1909 he graduated as BEng, with first-class honours.

In 1910 he became the pupil of the Sir Alexander Binnie, partner in the firm of Sir Alexander Binnie, Deacon and Sons. Apart from Mr Gourley's war service during the years between 1915 and 1918, he has remained with the same firm all his life, although in 1935 it was renamed Binnie, Deacon and Gourley and he became senior partner in 1949.

In 1951, when the Liverpool express was derailed at Weedon, Mr Gourley lost his right arm and left leg. His recovery, however, was remarkable and he soon learnt to write with his left hand. In 1935 he was President of the Institution of Water Engineers, in 1942 Chairman of the Association of Consulting Engineers and most recently was elected a life Honorary Member of the American Society of Civil Engineers.

BOOKS

Progress in Nuclear Energy, Series II—Reactors Vol I Ed R. D. Charpie, D. J. Hughes, D. J. Littler and M. Trocheris. 6¼in by 9¼in, 492 pp London 1956: Pergamon Press. Price £5.

This is the first volume in the second series of *Progress in Nuclear Energy* and, like the other first volumes in the various series, it is based on the Proceedings of the Geneva Conference in 1955. Enough has been written on the success of this conference, but it is now that the most important success is being felt with its maximum effect. This is the general declassification that took place for the conference, the results of which are now appearing in design work. Since Geneva the stifling curtains of secrecy seem to have been withdrawn at a steady and appreciable rate.

The amount of information admirably condensed into this volume is impressive. The fields surveyed are those of research reactors and power reactors, approximately equal emphasis being placed on the two broad groupings. The volume concludes with a catalogue of nuclear reactors, compiled from material available on April 15, 1956. In all, there are just under 500 pages of very useful material. The price however is high; it is to be hoped that the average reactor designer will be able to afford this outlay.

The section on research reactors begins with a chapter on the Canadian reactors at Chalk River; Zeep, NRX and the projected NRU, with the emphasis on NRX. The observed behaviour of this reactor and the operational procedures used are described in some detail. In this respect, it is the best chapter on research reactors in the book and will be useful to many future designers and experimenters. The writer would suggest to authors of future papers on reactors that, besides the physical design of a reactor, considerations influencing methods of operation and the methods themselves are well worth including. The number of persons with appreciable experience on reactors is a lot less than the number who will be involved in design and operation in the near future, and for some time the ratio of men with appreciable experience to those relatively fresh to the subject will continue to decrease. Therefore, do let us have more detailed papers on reactor operations.

The chapter on the US research reactors rightly places emphasis on the Material Testing Reactor and its developments. This is without doubt the doyen of research reactors at the moment; there are more reactors with this type of core than with any other, in operation or projected, throughout the world. There is also a review of the 'water boiler' type of research reactor with a description of a suggested water boiler incorporating several improvements on previous designs. Unfortunately no statements of the design power or fluxes are given.

It is unfortunate that the same symbols could not be used in the chapter on Soviet research reactors as in the other chapters; perhaps some standardization could be arranged. However, this is a small criticism considering the amount of information which is available in the chapter. A description is given of the 2MW reactor, using ordinary water and uranium enriched to 10%, which is being exported to Russia's satellites. It would be interesting to compare the price requested for this reactor with the price of equivalent reactors from the USA and Great Britain. Two of the points illustrated by the description of the 5MW (Elec) power station are the inelegance of Russian architecture by Western standards and the metallurgical excellence of their fuel elements. The elements have operated throughout the period of operation, up to the time of the paper, 4000MWD, without a failure; the paper suggests that the first charge of fuel produced more than 3,000MWD of thermal energy.

The UK research reactors are adequately and clearly described. The other European reactors suffer somewhat from being described by a collection of papers which must be described as a jumble of information. They could have been reported better in only two papers, one on the French and one on the Scandinavian reactors.

The section on power reactors begins with a detailed account of the pressurized water reactor which will become critical at Shippingport, Pa in 1957. This is followed by a chapter on the design and operating experience of the Argonne boiling water power reactor prototype, and chapters on the Aqueous Homogeneous, Sodium-Graphite and Fast power reactors respectively. All these chapters are from American authors; the only other chapter is by Sir Christopher Hinton on the Calder Hall type of power reactor. Thus about 95% of the reports on power reactors are from the USA. When one realizes that, for the next ten to fifteen years at least, both Great Britain and the USSR will probably have more installed electrical capacity derived from nuclear sources than the USA, this concentration of American reports is paradoxical; it is evidence of the dispersion of the US effort over a wide front with no well-defined objectives.

On points of detail in the book, there are a few misprints—all involving wrong numbers—and one figure caption has disappeared and turned up under another figure. These errors will be quickly discovered by the reader. The catalogue of reactors was not entirely up-to-date and in one instance, regarding 'Sleep,' the data given does not agree with the article describing this reactor in the main text. The index is adequate but the method of presentation is unusual and unwieldy. The printing and figures are excellent.

Finally, may a plea be made that isotopes are denoted with their mass number at the same level as the symbol for the element e.g. U235? There would be no loss of clarity and time would be saved by writers, typists and printers. I note that some publishers are already doing this. Perhaps Pergamon Press might help both themselves and their writers, by doing this in the second volume of *Reactors*. This second volume will have to be very good to be as good as volume one.

A. J. Salmon

Automatic Digital Computers M. V. Wilkes. 305 pp +116 figs. London 1956: Methuen

At one time a digital computer was a machine understood and used by a few specialists, but computers are now being manufactured in many places, particularly in America, and many designers are finding them an indispensable tool. The wide interest in these machines in this country may be gauged by the attendance at the Digital Computer Symposium organized last year by the Institution of Electrical Engineers in London. The attendance numbered over a thousand, and it was necessary to arrange parallel sessions for some of the papers.

In spite, however, of symposia of this sort there is still a wide body of engineers and scientists who want to know more about digital computers—what they are, and what can be done with them. To cater for their needs it will be necessary to plan more lectures and symposia on this important subject, particularly lectures catering for the needs of the beginner. A great deal can be done by the publication of suitable books on digital computers and it is a pleasure to the reviewer to see this important and valuable addition to the small number of works already existing.

Dr Wilkes's book provides a general introduction to the principles underlying the design and use of digital computers, but it is a book which can also be read with profit by the experienced worker in the field. It begins with a chapter on the development of the automatic digital computer and traces the development from the early work of Charles Babbage and indicates how many of his principles have been applied in the last two decades to the later electronic machines. This first chapter is very readable and brings out clearly the principles of the subjects and puts their application into proper perspective. The later chapters deal with the principles of logical design, the principles of programme construction, relay computers, storage, electronic switching and computing circuits, and the design and operation of digital computers. All these subjects are treated in some detail, but it is with the subjects of logical design and programming that the book is primarily concerned. Here the author has taken considerable pains to explain the principles by clear and accurate statements and by examples.

The last chapter on the operation of digital computers will be of special interest to that increasing body of people, who are considering obtaining a computer. It gives good advice on many of the problems of operation and indicates how these problems affect design. The important subject of fault-detecting circuits receives proper mention, and information is provided about the sort of operation which can be expected in practice and the organization necessary.

The later part of this chapter discusses the organization of a scientific computing centre, dealing with such matters as staffing, as well as the organization necessary for particular purposes, *e.g.* use of digital computers for business purposes, use of digital computers in a design office, and the use of digital computers for the control of industrial purposes.

According to the author the book should be of value to electronic engineers and to mathematicians, physicists, chemists, statisticians and others who are concerned with their use. The reviewer agrees with this view. This is a good book which can be read with profit by all concerned with digital computers and, at the same time, it provides a satisfactory introduction to the subject for beginners. The book is well illustrated and printed and appears to contain few errors.

Denis Taylor

Kempe's Engineers' Year-Book for 1957—62nd Edition Ed C. E. Prockter. 5in by 7in, 2,730 pp (2 vols) London 1956: Morgan Bros. Ltd. Price 82s. 6d.

There is nothing quite like Kempe's. Each year the traditional, slightly liturgical-looking, chunky volumes seem to grow in scope and content and reviewers run out of tired clichés, such as 'mine of information,' 'storehouse of knowledge' etc. That's what they are, of course, but one gets a little tired of saying so. The value of Kempe lies in its providing an easy reference to subjects on which one has little or no special knowledge. One does not go to it for one's pet subject: it is for other people's pet subjects. For this reason it is vital that it is kept fully up-to-date, particularly on rapidly developing subjects like atomic energy. Unfortunately, this cannot be said to have been achieved.

The main change in the 62nd edition is the inclusion of a new chapter on gearing by Dr H. E. Merritt. Metallurgically, some revision has taken place. Additional data is included on high-temperature alloy steels and, in the non-ferrous section, new text has been included on the magnesium alloys and the titanium alloys. From a nuclear energy point of view however there are serious omissions. Zirconium, for example, is dismissed in a few words as an additive to steel and its alloys are not mentioned at all. Nuclear fuel elements and their canning is not mentioned, neither is there any coverage of liquid metal technology. From the same point of view, the chapter on '*Atomic Power*' itself is a striking disappointment. Although it is stated to have been revised, the present reviewer can find little difference from the 1954 edition which even then represented the state of the art as it existed about 1950. This chapter is urgently in need of complete rewriting, to give a fair picture of what is now a very considerable industry in this country.

Another curious omission from Kempe is Chemical Engineering. One would have thought that this was at least as important—or at least of interest to more people than—as, for example, Railway Signalling. A section of the principles of chemical engineering and unit operations might well be a task for the 1958 edition.

Atomic Energy in Canada—2nd Edition Chalk River, Ontario 1956: Atomic Energy of Canada Ltd. Price $1.00

The 1956 edition of AECL's now well-known and attractive review of activities is superficially similar to the first edition but has been much increased in scope and interest. The sections on the NRX, NRU and NPD reactors have been somewhat expanded but the greatest difference is the inclusion of a competent completely new section on the elementary principles of atomic energy. The section on uranium mining which was a feature of the first edition has been dropped—presumably in view of the recent decision to declassify mining statistics. This might well form the basis of a useful separate new publication.

NUCLEAR ENGINEERING

edited by Charles F. Bonilla

Professor of Chemical Engineering
Chairman of the Nuclear Engineering Committee
Columbia University
Consultant, Brookhaven National Laboratory

The purpose of this text and reference book is to give the basic principles of the twelve main engineering disciplines involved in the design of nuclear reactor cores and power plants. It is more detailed and extensive than previous books, especially on fluid flow, heat transfer, stress analysis and power cycles. The necessary background in nuclear physics is provided. All the material is entirely up-to-date and includes new developments in mathematical analysis of plastic flow in thermal stress; design of orifices for protection of parallel coolant channels; relative evaluation of fuel element shapes and coolants. Illustrations and advanced specific analyses make the book valuable to the working design engineer as well as to the student.

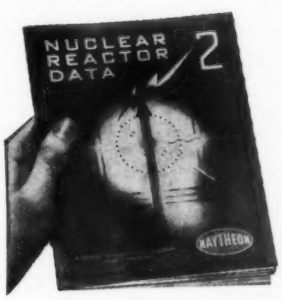
to be published shortly *750 pages* *about 71s 6d*

McGraw-Hill Series in Nuclear Engineering

McGraw-Hill Publishing Company Ltd

McGraw-Hill House : London, E.C.4

Just Published!



NUCLEAR REACTOR DATA

2nd Edition

This authoritative, new booklet lists principal characteristics of 142 of the World's reactors and nuclear power plants

$1 per copy —quantity discounts available

Write today for your copy. With this valuable compilation you can obtain an overall picture of the reactor situation, compare reactors, observe design and construction trends. Analyzes 12 types of reactors, gives data on 42 items for each. For your copy, address: Reactor Booklet, Raytheon Mfg. Co., Waltham 54, Mass. Please enclose $1 for each copy up to 10. Act now —supply limited.

RAYTHEON

RAYTHEON MANUFACTURING COMPANY
Waltham 54, Mass.

RESEARCH REPORTS

*The following reports have been made available to the public by the United Kingdom Atomic Energy Authority. They may be borrowed or photocopies obtained from the Science Library, London, Department of Industrial and Forensic Science, Belfast, the Mitchell Library, Glasgow, and the Central Libraries at Acton, Birmingham, Bristol, Kingston-upon-Hull, Leeds, Liverpool, Manchester, Newcastle-upon-Tyne and Sheffield. They are also deposited in the Copyright Libraries (i.e. British Museum; University Library, Cambridge; Radcliffe Science Library, Oxford; National Library of Scotland, Edinburgh; National Library of Wales, Aberystwyth) and in the Patent Office Library. Reports marked * may be purchased from Her Majesty's Stationery Office.*

Reports are also available in the United States, from the USAEC depository libraries, a list of which will be found in NUCLEAR SCIENCE ABSTRACTS. Reports for sale may be purchased in the United States from: Sales Section, British Information Services, 30 Rockefeller Plaza, New York 20, N.Y.

Atomic Energy Research Estabt.

Preliminary design parameters for 6.5 GeV S/R synchroton. W. Walkinshaw. (Nov 1956. 22 pp) AERE TP/R 2063

Phase stability in cyclotrons with the fixed frequency field law. L. B. Mullett. (Oct 1956. 11 pp) 2s. AERE GP/R 2071*

Industrial Group

Variational principle of one group diffusion theory for inhomogeneous reactors. R. T. Ackroyd. (Nov 1956. 4 pp) IGR-R/R 193

Plastic flow and the swelling of gas bubbles in uranium. J. A. Enderby. (Nov 1956. 13 pp) IGR-R/R 198

PROGRAMME

ICE Institution of Civil Engineers. IMechE Institution of Mechanical Engineers. IEE Institution of Electrical Engineers. IChemE Institution of Chemical Engineers. IP Institute of Physics. PS Physical Society. SCI Society of Chemical Industry. IM Institute of Metals. IMet Institution of Metallurgists. IMM Institution of Mining and Metallurgy. IPE Incorporated Plant Engineers. SIT Society of Instrument Technology.

FEBRUARY

Tuesday 5
LONDON IChemE **Liquid-liquid extraction** H. R. C. Pratt et al. 5.30 Geological Society, Burlington House

Thursday 7
LONDON IoR **Using ionizing radiations for preserving foods** R. S. Hannan. 5.30 at Junior Institution of Engineers, Pepys House, Rochester Row, SW1

LONDON IEE & IMechE **The place of engineering in university education** Sir Ifor Evans. 5.30 at the Institution of Electrical Engineers

Friday 8
LONDON IMechE **The economics of plant replacement and renewals** C. W. Griffiths. 6.00 at the Institution

Tuesday 12
MANCHESTER SIT **Computing technique to measurement and control** J. Wills. 7.30 at Manchester College of Technology

LONDON SCI **Some aspects of British Standards in relation to chemical engineering in the chemical industry** D. E. B. Greensmith. 5.30 at the Society

MANCHESTER IMechE **Informal discussion on nuclear power,** led by R. V. Moore. 6.45 at Engineers Club, Albert Square

Thursday 14
MIDDLESBROUGH SIT **Process control analysis** J. McMillan. 7.30 at Cleveland Scientific and Technical Institution

Friday 15
LONDON IMechE (BNEC) **Thomas Hawksley lecture** Some engineering problems in the industrial development of nuclear energy Sir Claude Gibb. Church House, SW1

Tuesday 19
BIRMINGHAM IChemE & SCI **Some aspects of atomic energy** C. M. Nicholls. 5.30 at Midlands Institute, Paradise Street

Thursday 21
LONDON IChemE **The processing of nuclear reactor fuels** R. Spence, C. M. Nicholls. 5.30 at the Royal Institution

BLACKBURN IPE **The application and maintenance of centrifugal pumps** G. O. Stevenson. 7.30 at Golden Lion Hotel

BIRMINGHAM IMechE **Power station auxiliary plant** Geoffrey F. Kennedy. James Watt Memorial Institute

Monday 25
LEEDS IPE **Fuel and the future** Prof A. L. Roberts. 7.30 at the University

Wednesday 27
CARDIFF SIT **Some application problems in fluid flow measurement** B. W. Balls. 6.45 at Physics Lecture Theatre, Cardiff College of Technology

NAMES IN THE NEWS

Dr Walter J. Worboys has been awarded the Society's Medal for 1957 of the Society of Chemical Industry, which is given not more than once every two years for conspicuous services to applied chemistry. Dr Worboys is commercial director of Imperial Chemical Industries and chairman of the Council of Industrial Design.

Sir Henry Wilson Smith has been made chairman of Powell Duffryn Ltd in succession to **Sir Herbert Merrett** who has resigned.

Mr C. R. Corness has been appointed secretary of Taylor Woodrow Construction Ltd, a main subsidiary of the Taylor Woodrow Group, in succession to **Mr L. Daniels**—who continues as secretary of the parent company. With the construction company, **Mr Leslie G. Cann,** who has been with TW for 18 years, becomes deputy chief surveyor under **Mr R. G. Puttock.**

Lieut-Col L. A. M. Bates-Oldham has been appointed a special director of International Combustion Ltd.

Mr V. S. Risoe MBE has joined the board of Associated Electrical Industries Overseas Ltd. Mr Risoe has had a varied career in the Far East with companies in the AEI group, having started as a student apprentice with BTH in 1934. While in Calcutta on the board of AEI (India) Ltd he was chairman of the India Committee of BEAMA and of the Calcutta branch of the IEE.

Sir Claude Gibb, Chairman of the Nuclear Power Plant Co Ltd has been appointed a vice-president of the Royal Society.

Mr Stafford Beer is the head of a new department of cybernetics recently set up by The United Steel Companies Ltd.

Negretti & Zambra Ltd, scientific instrument manufacturers have announced the following appointments: **Mr L. B. Lambert,** overseas manager. **Mr Arthur Muir,** home sales manager. **Mr R. L. Spiller,** chief technical correspondent.

Mr John Kay has been appointed representative for the West of England of Martonair Ltd, manufacturers of pneumatic hoists, cylinders, control valves and accessories.

Mr Ronald McKinnon Wood, chairman of Griffin & George Ltd, the laboratory furnishers and scientific instrument manufacturers, has been elected chairman of the London County Council. He starts his term of office in April.

Mr C. Murray has been appointed Manager (overseas) of British Insulated Callender's Cables Ltd. Mr Murray joined the old British Insulated in 1942 and later became Assistant Overseas Sales Manager.

Dr W. L. Pumphrey, Research Manager of Murex Welding Processes Ltd, Waltham Cross, Herts, has been awarded the degree of DSc in Industrial Metallurgy by the University of Birmingham for his work on hardenability, the transformation of steel during continuous cooling and the metallurgy of welding.

Mr W. J. M. Adams has been made managing director of Worthington-Simpson Ltd, the pump manufacturers

Mr H. G. Taylor becomes director of the Electrical Research Association in succession to the late **Dr S. Whitehead.**

Mr H. F. Tremlett has been made deputy director of the British Welding Research Association.

Mr H. A. Springer on 1 Jan became Joint Managing Director of Sangamo Weston Ltd with **Mr C. H. Bacon.** Mr Springer joined the company in 1932 and first became a director in 1953.

Mr Basil Z. de Ferranti, younger son of **Sir Vincent** and **Lady de Ferranti** was married in London on 17 Dec to **Miss Sara Gore,** daughter of the late Mr Christopher Gore and Lady Barbara Gore.

Mr E. E. Kennaird, sales manager, has joined the board of Cooke, Troughton and Simms Ltd, the Vickers subsidiary. At IOCO Ltd—another Vickers Group company—**Mr H. F. Judd,** the general sales manager, becomes a director.

Mr C. Metcalfe has been appointed a director of the EMI group and will act as managing director of the Electronics Division. **Mr W. C. Morgan,** commercial manager, has been made engineering director.

Prof Wilfred Murgatroyd, Professor of Nuclear Engineering at Queen Mary College (University of London) has just returned from a lecture tour to Peru under the auspices of the British Council.

755,903 **Improvements relating to the utilization of the nuclear combustion of hydrogen.** G. F. Hemens, London, Aug 29, 1956

According to this invention, water and other hydrogen-containing substances can be made to combine nuclearly with nitrogen, the air-water reaction being mentioned specifically. This H-N reaction constitutes the second half of the Bethe-Weizsäcker cycle which is held to be responsible for the energy release in the sun and stars. From his interpretation of published accounts of nuclear weapon test explosions, the patentee concludes that, in a secondary effect of the bomb, a H-N reaction takes place in the water vapour cloud and he concludes that such a reaction could be initiated with a temperature of about 7,000°C instead of the several millions commonly held to be necessary. It is proposed to initiate such reactions by the use of an ordinary high explosive containing a small quantity of tritium, deuterium or lithium compounds. This could even be in the form of a match. The specification describes apparatus in which the reaction might be performed.

761,404 **Improved methods of and means for converting the energy of nuclear radiations into useful electrical energy** Radio Corporation of America, New York, Nov 14, 1956

An electric battery may be formed by irradiating semiconductors with ionizing radiations. In its simplest form the invention comprises a source of radiation and a p-n junction device, either of the 'grown' or the alloy types. The source may be: polonium or uranium (alpha emitters), strontium-90 or tritium (beta emitters) or cobalt-60 (gamma). For the junction, if n-type germanium is used, the material for the p-region may be indium, boron or gallium. If p-type germanium or silicon is used, the alloy material may be lead, antimony, or gold-antimony. Point contact transistors may also be used.

The radiations from the source interact with the valence bonds, causing charge carriers (electrons and holes) to be liberated within the solid. If the energy quanta are sufficient, these charge carriers take part in a current induction process. Quoted as an example, with a 50 millicuries Sr-90 source the open circuit voltage in a germanium transistor is 30mV: with silicon, it is 200mV.

The advantage of the system is the very small size of the battery—of the order of a fraction of a cubic cm. It is also very robust and as a primary source of energy it is limited only by the life of the source.

Further developments of this principle embodying a number of junctions are described.

755,598 **Process for carrying out nuclear fission reactions** Stichting voor Fundamenteel Onderzoek der Materie, Utrecht, Aug 22, 1956

In a thermal conversion reaction the reactivity changes with burnup of fuel and an ever-increasing number of neutrons have to be wastefully absorbed to keep the reproduction factor equal to unity. These changes may be minimized by adjusting the ratio of moderator to fuel present and this may conveniently be done in a homogeneous type of reactor.

751,700 **Nuclear Reactor** Stichting voor Fundamenteel Onderzoek der Materie, Utrecht, July 4, 1956

Relating to homogeneous reactors, the novel feature of this invention is the use of a shield containing bismuth. This material is suitable for shielding because it has a very high absorption capacity for electromagnetic radiations, and it is said that 40cm of bismuth metal is equivalent to 150cm of concrete. This would result in a much smaller plant. The invention is claimed to be of advantage when bismuth is used as a reflector (it has a low neutron capture cross section combined with a high scattering cross section). Thus the shield may be combined with the reflector. Cooling of the shield would of course be necessary and the invention includes means for doing this. A typical application is described in some detail.

755,291 **Improvements in devices for the evacuation of heat.** Société Rateau, Paris, Aug 22, 1956

By way of illustration, the invention is applied to cooling a horizontal cylindrical gas-cooled reactor core. The core is in two separate cylinders separated by a space and the coolant channels in each half are horizontal. Coolant is supplied through an annular volute chamber surrounding the core and reaches the central space through curved vanes. On passing through the fuel channels, the heated gas is removed at both ends of the core through collecting chambers.

In its passage through the volute casing and the vanes to the centre of the core the velocity decreases and the static pressure increases. Thus, channels near the periphery will receive less coolant than the centre ones. Since the heat output is greater in the centre, this gives a more uniform rate of heat removal. The system thus acts as a form of diffuser, the efficiency being aided by the fact that the coolant channels are exercising a continuous boundary layer control.

Further refinements of slot geometry are possible and are indicated in the specification.

755,495 **A process of and apparatus for carrying out nuclear reactions.** Stichting voor Fundamenteel Onderzoek der Materie, Utrecht, Aug 22, 1956

In any homogeneous or slurry reactor, pumping presents one of the most difficult problems. This may be overcome by using gravity flow through the core vessel with a gas-lift for the return. In this system, the liquid circuit incorporates a vertical riser at the bottom of which a gas is introduced. This raises the fuel solution to the header system where the gas is removed.

An important advantage claimed is that in addition to the pumping function, the gas also washes the solution once during every circuit and arrangements can be made to remove gaseous fission products and, in the case of D_2O and H_2O solutions, products of radiolysis. After removal from the solution, the gas is purified and recirculated. Suitable gases for the system are discussed.

756,014 **Improvements in or relating to reactors employing nuclear fissionable material** Westinghouse Electric International Company, New York, Aug 29, 1956

The proposed reactor uses fuels in the form of a bed of discrete pellets some at least of which contain fissionable material. These are contained on a perforated tray in a pressure vessel through which a coolant is passed. At rest, the pellets are in a sub-critical condition but on the introduction of a coolant-fluid the bed is fluidized and the pellets are moved into such a position that the reaction becomes divergent. The fluid may act as a coolant, moderator or both.

The reactor is claimed to be inherently safe because failure of the fluid pumping system will result in the collapse of the fuel bed, thus decreasing the fuel-moderator ratio and bringing sub-criticality.

Means are described in the specification for the removal of pellets for reprocessing and for charging of fresh ones.

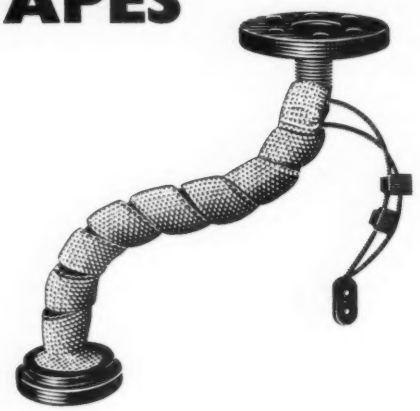
754,183 **Improvements in nuclear chain reactors.** Allemanna Svenska Elektriska AB, Vasteras, Sweden

Using tubular fuel elements, this reactor is liquid-metal cooled and heavy-water-moderated. The liquid metal such as sodium is circulated through the hollow elements which are clad on the outside with a double tube of zirconium or other suitable material. The space between the two cladding tubes is filled with gas such as helium. This reduces heat loss to the heavy water moderator which is kept at a low temperature—below 100°C. An alternative fuel element consists of a solid rod, the liquid metal coolant passing between it and the inner cladding skin.

These abstracts are made from British Patent Specifications with the permission of the Controller of Her Majesty's Stationery Office. Complete specifications may be obtained from the Patent Office (Sales Branch), 25 Southampton St, London, WC2, 3s. a copy (inc postage, inland & abroad)

HEAT FOR SCIENCE & INDUSTRY

HEATING TAPES



Electrothermal provides the ideal solution for heating surfaces of any kind. The unique elastic heating tape is supplied in standard lengths and widths by your usual laboratory supplier.

HEATING TAPES—up to 450°C.
ARMOURED HEATERS—up to 800°C.
PIPE HEATERS—up to 100°C.

Please request leaflet

ELECTROTHERMAL

ENGINEERING LIMITED · 270 NEVILLE ROAD · LONDON, E.7

GRAngewood 9911/5

FOR HIGH PRESSURE PIPE LINES THE UNIVERSAL SPECIFICATION IS ERMETO

Because of the increased efficiency they have brought to pipe line systems, ERMETO fittings have helped in the achievement of many fine engineering enterprises. ERMETO joints may be broken and remade without loss of pressure-tightness.

Technical literature gladly sent on request.

ERMETO

VALVES and COUPLINGS

BRITISH ERMETO CORPORATION LTD., MAIDENHEAD, BERKS. Tel.: 2271/4

THE PHYSICAL SOCIETY'S

1957 Exhibition of Scientific Instruments and Apparatus

25th—28th MARCH

Royal Horticultural Society's Halls, London

The latest developments in British scientific instruments will be shown.

The Handbook of the 41st Exhibition is essential for all whose work involves instrumentation, being an up-to-date guide to the source of the instruments which they require from day to day. Price 6s., postage 1s 6d.

The Physical Society,
1 Lowther Gardens, Prince Consort Road, London, S.W.7

REICHERT
SHANDON

remote-controlled microscopes

THE metallographic examination of radio active materials *behind efficient shielding* presents formidable instrumentation problems if full advantage is to be taken of the versatility of modern metallurgical microscopes with their multitude of adjustments and complex controls.

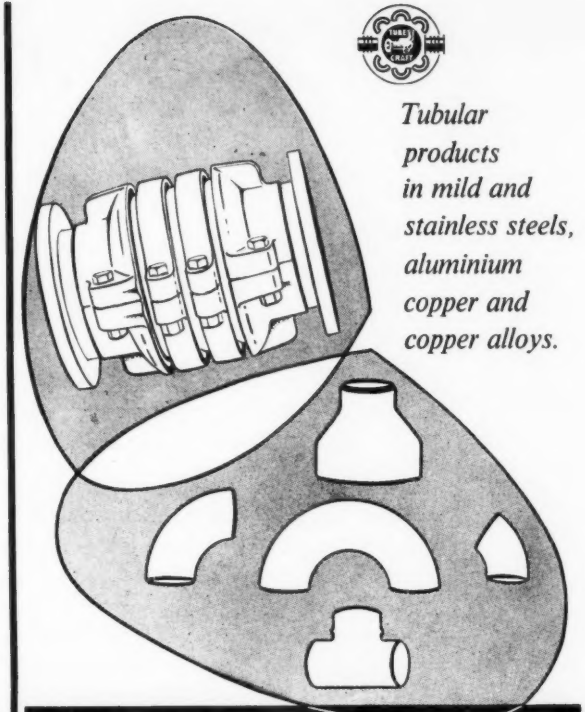
In close co-operation with the United Kingdom Atomic Energy Authority the *Reichert-Shandon Remote-controlled Microscope* has been developed and is now commercially available to the steadily increasing number of laboratories which are faced with the problem of examining active or toxic materials.

By means of an optical train passing through the shielding, visual microscopy and photomicrography is possible—conveniently and safely. All microscope adjustments, such as coarse and fine focussing, operation of iris diaphragms, stage traverses and rotation, insertion, withdrawal and rotation of polarisers and analysers and changing of objectives, are remotely controlled from outside the shielding. In addition, phase-contrast or dark-field illumination can be applied and micro-hardness tests can be carried out in rapid succession and whilst the radio-active specimen remains in position on the microscope stage.

Further information is obtainable from

SHANDON SCIENTIFIC COMPANY LTD.
6 CROMWELL PLACE, LONDON, S.W.7

Telephone: KNightsbridge 1131/3



Tubular products in mild and stainless steels, aluminium copper and copper alloys.

MUNRO & MILLER LTD
AFRICA HOUSE, KINGSWAY, LONDON, W.C.2
Telephone HOLBORN 5572 Telegrams "TUBECRAFT" LONDON

YEAR BOOK and BUYERS GUIDE

This new annual publication is a complete and comprehensive guide to the whole field of nuclear activity. Containing over 500 pages it will be indispensable to all firms, atomic energy agencies, and research workers engaged in nuclear work

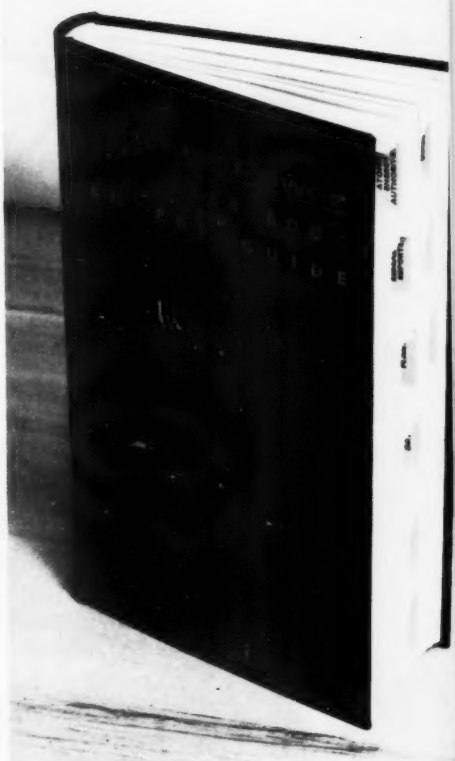
United Kingdom
£2.2.0 plus 1/- postage and packing

US and Canada
$8 plus 50c postage and packing

other countries
£3.3.0 plus 1/6 postage and packing

Orders can now be accepted

NUCLEAR POWER
3 PERCY STREET
LONDON W1



FIRTOP FILTERS & *motorised* VALVES

FIRTOP

FILTERS for pressures up to 5,000-lbs.; capacities to 2,500 g.p.h.; filtration to 1½ microns if required.

MOTORISED VALVES, sizes 2-in. to 12-in. for pre-set electro-automatic operation. For all standard voltages.

FIRTOP—perfectly "at home" in nuclear engineering.

G.&A. FIRKINS LTD.
FIRTOP WORKS,
STOKE HEATH,
BROMSGROVE, WORCS.
Tel: BROMSGROVE 3246/7/8

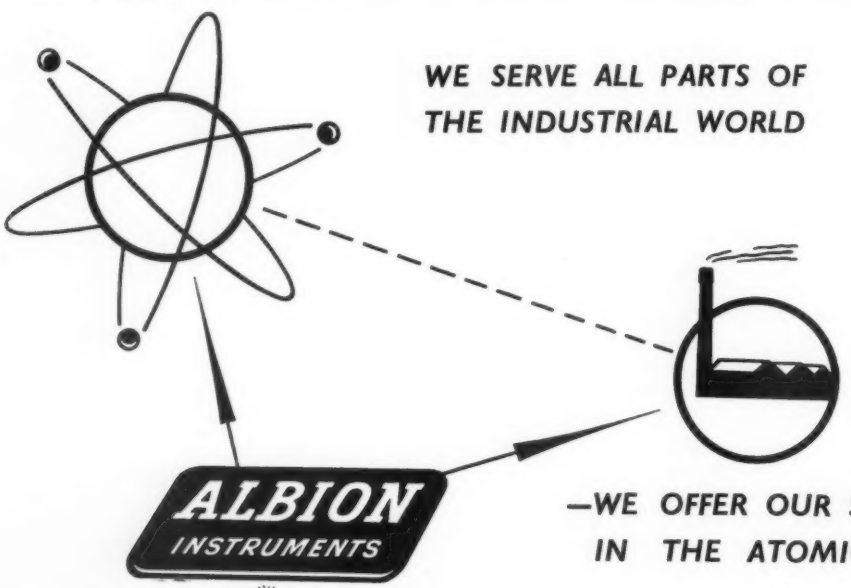
HENRY GARDNER & CO. LTD

2 METAL EXCHANGE BUILDINGS
LONDON EC3

suppliers of

CADMIUM
BISMUTH
INDIUM
LEAD
TITANIUM
TITANIUM ALLOYS

Cables: NONFERMET London Tel: MANsion House 4521 and at BIRMINGHAM, MANCHESTER, GLASGOW



WE SERVE ALL PARTS OF THE INDUSTRIAL WORLD

ALBION INSTRUMENTS

—WE OFFER OUR SERVICES IN THE ATOMIC FIELD

- **PRECISION INSTRUMENTS**
- **ELECTRICAL AND MECHANICAL MEASURING UNITS AND MACHINES**
- **SMALL PARTS** ● **DIE CASTINGS**

INSTRUMENT DIVISION
B. & F. CARTER & CO. LTD.
ALBION WORKS, BOLTON 23, ENGLAND
TEL. BOLTON 4344 (3 LINES)

A TIMEG
NEOPRENE
BOILER SUIT

TIMEG LTD

SPECIALISTS IN PROTECTIVE CLOTHING FOR
ATOMIC POWER DEVELOPMENT

Protective clothing is Timeg's business. They manufacture and supply uniforms and safety accessories in various designs to resist water, acids alkalis, chemicals, fumes and gases. All these uniforms are liberally cut with scientifically designed ventilation to ensure maximum comfort under working conditions.

No matter how large or small your requirements consult the Research Department of

TIMEG LTD.
102 WARDOUR STREET, LONDON, W.1
Telephone: Gerrard 1191/2

energia nucleare

The bi-monthly review of CISE (the Information Centre for Studies and Experience)

This journal covers all important developments in the field of nuclear technology in Italy

We announce:
ORIGINAL PAPERS IN ENGLISH

To keep abreast of trends in Italy you should read **Energia Nucleare**

Subscription rate per annum - **45s**
Subscription for both 1956 and 57 **75s** Per copy 7s 6d

Subscription to sole agents
ROWSE MUIR PUBLICATIONS LTD
3 Percy Street, London, W1

energia nucleare

Head Wrightson's plan for the future —theirs and yours

Growing commitments in Nuclear, Metallurgical and Chemical Engineering have led to the creation of new research facilities at Thornaby-on-Tees.

Applications are invited for both Senior and Junior positions in the following fields:—

Heat Transfer and Fluid Flow
General Chemical Engineering
Physical Metallurgy (with special reference to Welding)
Experimental Stress Analysis

There are excellent openings for men of first-rate academic and experimental ability, who will find opportunities for really creative work in a good atmosphere.

Head Wrightson's are the main contractors for the design, construction and erection of Heat Exchangers at the Bradwell Nuclear Power Station.

Apply in writing to Personnel Manager Dept. RD/3.

HEAD WRIGHTSON & CO., LTD.

TEESDALE IRON WORKS THORNABY ON TEES.

THE NUCLEAR POWER PLANT CO LTD

URGENTLY REQUIRE

PHYSICISTS

for expanding programme on

REACTOR PHYSICS AND SHIELDING

This Company is engaged on the Design and Construction of Nuclear Power Stations for all parts of the world.

A competitive salary will be offered to the successful applicants who will be required to work at Booths Hall, Knutsford.

Where necessary, deferment of national service will be obtained and opportunity given for attending training courses in reactor technology.

Written applications with an accompanying sheet giving details of age, education, qualifications and career to date should be sent to:

THE ASSISTANT SECRETARY,
THE NUCLEAR POWER PLANT CO LTD,
BOOTHS HALL, KNUTSFORD, CHESHIRE

Please mark your envelope NP/SV/1.

THE G.E.C.–SIMON–CARVES ATOMIC ENERGY GROUP, ERITH

Simon-Carves Ltd. have vacancies at the Erith Headquarters of the Group for:

A DESIGN ENGINEER for primary design work on steam-raising heat exchangers. An Hons. graduate is required with relevant industrial experience.

A DESIGN ENGINEER for project work on power station ancillary mechanical plant, including circulating water systems. A university graduate is required with relevant industrial experience.

A DESIGN ENGINEER for work on large pressure vessels. The candidate must have H.N.C. as a minimum qualification and have had pressure vessel experience relating to the oil refining or chemical industries. He should be conversant with English and American codes; fabrication experience would be valuable but not essential.

A MECHANICAL ENGINEER, CHEMICAL ENGINEER or **PHYSICIST** for heat transfer research. An Hons. graduate is required with experience of relevant experimental work.

A PHYSICIST for development and application of leak location and detection techniques relating to industrial plant. A university graduate is required who has had high vacuum experience.

Applications should be addressed to:

Simon–Carves' Manager,
G.E.C.–Simon–Carves Atomic Energy Group,
Fraser and Chalmers Engineering Works,
Erith, Kent

CLASSIFIED ADVERTISEMENTS

RATES	Classified advertisements are charged at 4s. per line. Semi-display setting £3 per single-column inch. 5% is allowed to trade advertisers for six insertions. 10% for 12 consecutive insertions. Box numbers will be charged 1s. extra
REMITTANCES	Cheques and postal orders should be sent to Rowse Muir Publications Ltd with the order for the advertisement
PRESS DAY	Advertisements must be received not later than 22nd February for the March issue
TERMS	All advertisements are strictly net and must be prepaid
HEAD OFFICE	All advertisements should be addressed "Classified Advertising," NUCLEAR POWER, 3 Percy Street, London W1
BOX OFFICE REPLIES	NUCLEAR POWER, 3 Percy Street, London W1

SITUATIONS VACANT

ATOMIC ENERGY. An exceptional and exciting opportunity occurs for an engineer-journalist (age between 25-35 years) at the Erith (Kent) headquarters of the GEC—Simon-Carves Atomic Energy Group. The successful candidate will find himself surrounded by a large staff of brilliant engineers and scientists who possess a vast fund of original and highly technical knowledge but who are genuinely too busy to sit down and write about it. It will be the successful candidate's duty to obtain from them, largely by discussion, information which he will prepare in a form suitable for the technical press and the Group's own technical publications. Candidates **must** be scientifically qualified and **must** have experience in technical journalism. Salary will be commensurate with the importance attached to the work. Apply giving full details of age, education, experience and salary required, to the Staff Manager, The General Electric Co Ltd, Magnet House, Kingsway, London WC2.

RESEARCH FELLOWSHIP IN HEAT TRANSFER AND FLUID FLOW. Applications are invited for a research fellowship tenable in the Nuclear Engineering Laboratory of QUEEN MARY COLLEGE (University of London). The successful applicant will be expected to carry out research on fundamental fluid motion and heat transfer problems associated with the use of liquid fuels in nuclear reactors. The post would particularly appeal to someone interested in experimental fluid dynamics. The appointment will be initially for three years and the remuneration in the range of £750-£1,000. Application forms, available from the Registrar, Queen Mary College, Mile End Road E1, should be returned by 16th February.

FOSTER WHEELER, LIMITED, Steam Division, require DESIGN ENGINEERS for their London office, to work on nuclear power and propulsion projects. Applicants should be of Degree or Corporate Membership of I.Mech.E. standard and should preferably have served an apprenticeship and be free from National Service commitments. Design experience of high-pressure steam plant or chemical plant is desirable. The positions are permanent and good salaries would be paid commensurate with qualifications and experience. Successful applicants would join an expanding department with good opportunities for advancement for keen men of real technical ability. Pension fund. Staff dining room facilities. Applicants should state age and detail experience and qualifications.—Foster Wheeler, Limited, 3 Ixworth Place, London, S.W.3.

MANAGEMENT SELECTION LTD have been retained to advise on the selection of a

SENIOR STEAM TURBINE ENGINEER

for an important industrial Group concerned with atomic developments with a long experience to put to the design of steam turbines for use with nuclear reactors in power stations. The prospects in this field of industry are exceptionally good and afford corresponding scope for the man with the ability to take advantage of them.

Candidates must have an engineering degree and extensive experience of steam turbine design. The appointment will be based on London and may require occasional travel overseas. Preferred age 35 to 45.

The salary range will interest candidates earning between £2,500 and £3,500 and there is a service agreement.

Please send brief information in strict confidence to E. P. Kelsall, Management Selection Limited, 17 Stratton Street, London W1, quoting reference (MQ215). No information will be passed to our clients without candidates' permission after full confidential discussion.

ATOMIC ENERGY
RESEARCH ESTABLISHMENT
HARWELL

has vacancies in the Isotope School for the following:—

CHEMIST/BIOCHEMIST (ref. 689/215) to assist with the training of post-graduate students.

Some biochemical experience required, preferably involving the use of radio-active isotopes. Ability to lecture and demonstrate an advantage.

The post will be graded as Scientific or Experimental Officer according to qualifications and experience.

PHYSICIST (ref. 688/215) to lecture on nuclear physics to post-graduate students, and to carry out research on new techniques. Preferably some experience in the field of atomic energy required. The post will be graded as Scientific/Senior Scientific Officer according to age and experience.

SALARIES: Senior Scientific Officer, £1,155—£1,355; Scientific Officer, £615—£1,065 (Qualifications—1st or 2nd Class Honours degree or equivalent); Experimental Officer, £940—£1,155 (Qualifications—G.C.E. in 5 subjects including 2 scientific subjects at Advanced level, or equivalent).

Send POST CARD for further details and application form, which must be returned by February 6, 1957, to Establishment Officer, A.E.R.E., Harwell, Didcot, Berks., quoting appropriate reference.

CENTRAL ELECTRICITY
AUTHORITY HEADQUARTERS

require the following in the Station Development Sub-Branch in London:

(a) SECOND ASSISTANT ENGINEER
(b) THIRD ASSISTANT ENGINEER
(c) FOURTH ASSISTANT ENGINEER

The Sub-Branch is responsible for the planning of generating capacity throughout England and Wales; selection of station sites to implement the Nuclear Power Programme; selection of sites for orthodox power stations; obtaining statutory and other consents for both.

Candidates should posses an Honours Degree or qualifications for membership of the I.Mech.E., I.C.E. or I.E.E. and, preferably, experience of economic studies or the problems of siting power stations, e.g. geology, ground exploration, thermal and hydraulic aspects of the use of river and sea water for cooling purposes, discharge and dispersal of chimney emissions or questions of town and country planning.

Salaries within scales:
(a) £1,045-£1,395 p.a.
(b) £977-£1,190 p.a.
(c) £772-£956 p.a.
according to ability.

Application forms (AE.6), obtainable from D. MOFFAT, DIRECTOR OF ESTABLISHMENTS, Winsley Street, London, W.1, should be returned by 8th February.

GOOD PRACTICAL ENGINEER, age 30/45, with sound technical background, required for interesting work of national importance in the field of engineering manufacture. The position offers good opportunities for advancement to men with personality and the ability to put ideas across to industrial personnel at all levels of responsibility. Although not a sales job, it will entail occasional travelling in Britain and residence in the Leicester area. Salary will be commensurate with experience and qualifications. Superannuation scheme. Reply giving full details to Box No. B/192 Nuclear Power.

HEAT TRANSFER AND FLUID FLOW.—RESEARCH AND DEVELOPMENT ENGINEER required by an old-established engineering company in the Glasgow area. Applicants, aged 25-30, should have a university Honours Degree in engineering and some research experience. The work would involve the theoretical design and practical testing of new types of heat exchanger. A good salary would be paid to an applicant with the necessary qualifications. Apply, giving age and full particulars.—Box B/174 Nuclear Power.

INDEX TO ADVERTISERS

Acheson Colloids Ltd	15
AEI Lamps & Lighting Co Ltd	November
AEI–John Thompson Nuclear Energy Co Ltd	32
Aerox Ltd	December
Air Control Installations Ltd	June
Allen, P. W. & Co	January
Amal Ltd	January
Appleby & Ireland Ltd	December
Atomwirtschaft	January
Automatic Telephone & Electric Co Ltd	November
Babcock & Wilcox Ltd	November
Bailey, N. G. & Co Ltd	November
Baldwin Instrument Co Ltd	January
Berk, F. W. & Co Ltd, Schori Division	January
Blakeborough, J. & Sons, Ltd	October
Board of Trade	Inside Back Cover
British Acheson Electrodes Ltd	October
British Ermeto Corp. Ltd	33
British Oxygen Gases Ltd	January
British Thomson-Houston Co Ltd, The	May
Bryce Electrical Construction Co Ltd	December
Butterfield, W. P. Ltd	January
Cape Asbestos Co Ltd, The	October
Carbon Dioxide Company, The	October
Carter, B. F. & Co Ltd	35
Cawkell, A. E.	December
Central Electricity Authority	July
Cinema-Television Ltd	October
Cockburns Ltd	14
Cooling Towers Ltd	July
Cossor Instruments Ltd	January
Costain–John Brown Ltd	May
Crossley Bros. Ltd	16
Darlington Insulation Co Ltd	January
Davenport Engineering Co Ltd	24
Davidson & Co Ltd	22
Dewrance & Co Ltd	November
Dexion Ltd	October
Dowty Nucleonics Ltd	July
Dynatron Radio Ltd	January
Edwards High Vacuum Ltd	May
Ekco Electronics Ltd	January
Electric Furnace Co Ltd	January
Electrothermal Engineering Ltd	33
Elliott Bros (London) Ltd	6
Endecotts (Filters) Ltd	August
Energia Nucleare	36
Engis Ltd	May
Erhard, Johannes	4
Ericsson Telephones Ltd	7
Extrudex Ltd	June
Fairey Aviation Co Ltd, The	October
Fielden Electronics Ltd	January
Firkins, G. & A. Ltd	35
Fleming Radio (Developments) Ltd	12
Fulmer Research Ltd	November
Gardner, Henry & Co Ltd	35
General Electric Co Ltd	30
General Radiological Ltd	July
Gordon, James & Co Ltd	11
Grazebrook, M. & W. Ltd	January
Ham, Baker & Co Ltd	December
Harvey, G. A. & Co (London) Ltd	8
Haworth, F. (A.R.C.) Ltd	December
Hayward Tyler & Co Ltd	January
Head, Wrightson & Co Ltd	37
Heather Filters Ltd	January
Her Majesty's Stationery Office	May
Hilger & Watts Ltd	January
Hobson, H. M. Ltd	October
Honeywell-Brown Ltd	October
Hopkinsons Ltd	November
Howden, James & Co Ltd	29
Humphreys & Glasgow Ltd	19
Imperial Chemical Industries Ltd	December
Isotope Developments Ltd	14
Johnstone, Archibald Ltd	November
KDG Instruments Ltd	December
Kent, Ltd, George	November
Klaxon Electrical Engineers Ltd	December
Kodak Ltd	3
Labgear (Cambridge) Ltd	2
Lead Development Association	September
Leybold Vacuum Sales Ltd	June
Londex Ltd	November
Lyons Ltd, Claude	December
Magnetic Valve Co Ltd	13
Mallinson, William & Sons Ltd	10
Marston Excelsior Ltd	5
Martonair Ltd	January
McGraw-Hill Publishing Co Ltd	75
Measuring Instruments (Pullin) Ltd	December
Metropolitan-Vickers Electrical Co Ltd	January
Micanite & Insulator Co Ltd	December
Miller, P. & L. Ltd	June
Mills Scaffold Co Ltd	Back Cover
Mitchell Engineering Ltd	Front Cover
Moler Products Ltd	December
Mollart Engineering Ltd	January
Morgan Crucible Co Ltd, The	12
Mullard Ltd	November
Mullard X-Ray Division	9
Munro & Miller Ltd	34
Murex Welding Processes Ltd	January
Nash & Thompson Ltd	December
New Metals & Chemicals Ltd	December
Nuclear Enterprises (GB) Ltd	January
Nuclear Graphite Ltd	28
Nuclear Power Plant Co Ltd, The	37
Nuclear Research Applications	May
Ozonair Engineering Co Ltd	October
Panax Equipment Ltd	December
Pascall Ltd	January
Philips Electrical Ltd	1
Physical Society Ltd	33
Plessey Co Ltd	October
Powell Duffryn Carbon Products Ltd	23
Pye Ltd (Industrial TV Division)	26
Racal Engineering Ltd	11
Raytheon Manufacturing Co	75
RFD Co Ltd (Protective Safety Division)	June
Rotameter Manufacturing Co Ltd	August
Sangamo Weston Ltd	15
Savage & Parsons Ltd	Inside Front Cover
Shandon Scientific Co Ltd	34
Shaw-Petrie Ltd	18
Shell Chemical Co Ltd	17
Shell Mex & BP Ltd	November
Silica Gel Ltd	16
Simplifix Couplings Ltd	January
Smith, J. & Sons (Clerkenwell) Ltd	13
Southern Instruments Ltd	July
Stephen, R. A. & Co Ltd	June
Stillite Products Ltd	December
Sunvic Controls Ltd	38
Talbot Stead Tube Co Ltd	25
Taylor Woodrow Ltd	November
Teddington Aircraft Controls Ltd	January
Temperature Ltd	July
Thermo-Plastics Ltd	June
Thompson, John Ltd	November
Timeg Ltd	36
Titanium Metal & Alloys Ltd	November
Tube Investments Ltd	May
20th Century Electronics Ltd	August
Unit Superheater & Pipe Co Ltd	27
United Nations Information Service	August
Veedip Ltd	December
Vokes Ltd	10
Weir, G. & J. Ltd	21
Wharton Crane & Hoist Co Ltd	20
Whessoe Ltd	January
Wilkinson Rubber Linatex Ltd	December
Wright Anderson & Co Ltd	November

NUCLEAR POWER is published by Rowse Muir Publications Ltd, 3 Percy Street, London, W1, England, and printed by The Haycock Press, Ltd, SE5

HELP FOR OVERSEAS TRADERS

MANUFACTURERS AND TRADERS are invited to apply for a useful booklet which describes how the Board of Trade, the Export Credits Guarantee Department, and a world network of UK commercial officers overseas can help and advise about export trade.

The booklet gives details of helpful Government publications; addresses of Regional offices in the United Kingdom; and a list of places abroad where UK officials are at your service.

A GUIDE TO GOVERNMENT SERVICES FOR EXPORTERS

THE BOOKLET tells you how to set about getting answers to questions about tariffs and duties, getting lists of likely importers of your goods, protecting yourself against non-payment, appointing agents, taking part in overseas trade affairs, making arrangements for a business trip abroad, and much more that will interest exporters old and new.

It can be obtained from any of the Regional Offices of the Board of Trade; from the Board's Headquarters at Horse Guards Avenue, London, S.W.1; or from Export Services Branch at Lacon House, Theobalds Road, London, W.C.1.

BOARD OF TRADE

ALTAZIMUTH PARABOLOID RADIO REFLECTOR AT THE JODRELL BANK SITE, BUILT FOR MANCHESTER UNIVERSITY AND THE DEPARTMENT OF SCIENTIFIC & INDUSTRIAL RESEARCH. CONSULTING ENGINEERS: HUSBAND & CO., SHEFFIELD. STEELWORK CONTRACTORS: UNITED STEEL STRUCTURAL CO. LTD.

Scaffolding by

MILLS

RADIO SIGNALS have been received from points in outer space where nothing can be seen even with the aid of the most powerful telescopes.

It has been established that these signals are of natural origin, from stars unknown to classical astronomy because the radiations from them are in sections of the spectrum which do not constitute light visible to the human eye.

The study of the number and nature of these stars, and the part they play in the universe, has created the science of radio astronomy, which this great new instrument, the first of its kind in the world, will do much to further.

SOME ENGINEERING DETAILS:

Height to the top of the Towers: 185 ft. Height to the Trunnion Bearings: 166 ft. 8 ins. Internal diameter of the Bowl: 250 ft. Depth of the Bowl: 73 ft. 4 ins. Weight of the Bowl, with cross girder: 900 tons—**carried on MILLS Scaffolding during construction.**

MILLS SCAFFOLD CO. LTD.

(A subsidiary of Guest, Keen & Nettlefolds Ltd.)

HEAD OFFICE: TRUSSLEY WORKS, HAMMERSMITH GROVE, LONDON, W.6 RIVERSIDE 3011 (10 LINES)